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AD-A142 071

IDA RECORD DOCUMENT D-19

F-15 AN/APG-63 RADAR CASE STUDY REPORT

(IDA/OSD R&M STUDY)

Paul F. Goree
IDA R&M Case Study Director

August 1983

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Prepared for
Office of the Under Secretary of Defense for Research and Engineering
and
Office of the Assistant Secretary of Defense
(Manpower, Reserve Affairs and Logistics)

INSTITUTE FOR DEFENSE ANALYSES

84 06 04 013

IDA Log No. HQ 83-258

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. ADA1?2071	3. RECIPIENT'S CATALOG NUMBER
4. TI… (and Subtitle) F-1… AN/APG-63 Radar Reliability and Maintainability Case Study Report		5. TYPE OF REPORT & PERIOD COVERED Final July 1982 - August 1983
		6. PERFORMING ORG. REPORT NUMBER IDA Record Document D-19
7. AUTHOR(s) Paul F. Goree IDA R&M Case Study Director		8. CONTRACT OR GRANT NUMBER(s) MDA 903 79 C 0018
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Defense Analyses 1801 N. Beauregard Street Alexandria, VA 22311		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Task T-2-126
11. CONTROLLING OFFICE NAME AND ADDRESS Office of the Assistant Secretary of Defense (MRA&L), The Pentagon Washington, D.C. 20301		12. REPORT DATE August 1983
		13. NUMBER OF PAGES 362
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) DoD-IDA Management Office 1801 N. Beauregard Street Alexandria, VA 22311		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

None

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

reliability, maintainability, readiness, case study, program structuring, lessons learned, F-15, APG-63, radar

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document records the activities and presents the findings of the F-15 AN/APG-63 Radar Case Study Working Group part of the IDA/OSD Reliability and Maintainability Study, conducted during the period from July 1982 through August 1983.

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Paul F. Goree
IDA R&M Case Study Director

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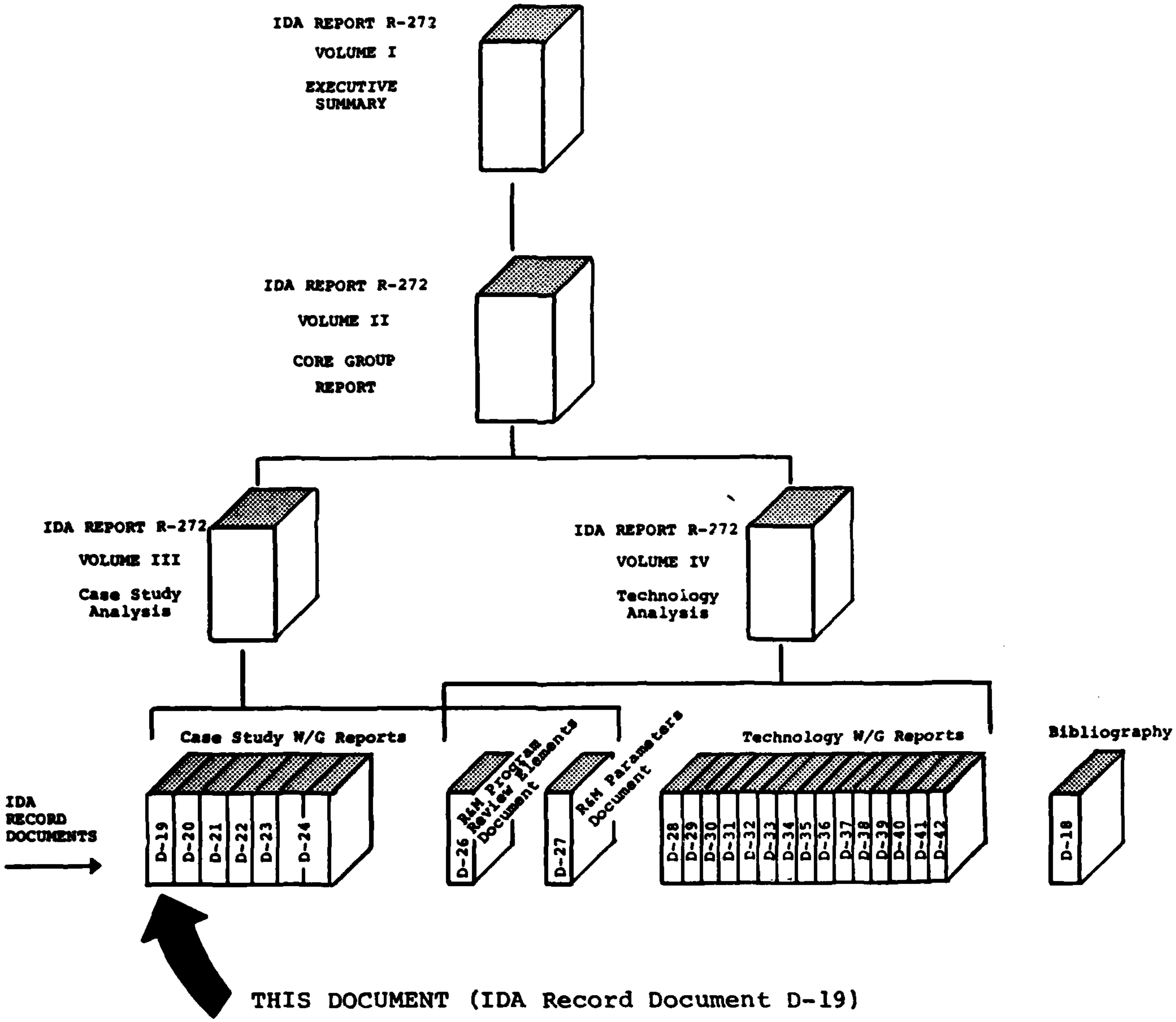
INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311

Contract MDA 903 79 C 0018
Task T-2-126

RELIABILITY AND MAINTAINABILITY STUDY

— REPORT STRUCTURE —



THIS DOCUMENT (IDA Record Document D-19)

PREFACE

As a result of the 1981 Defense Science Board Summer Study on Operational Readiness, Task Order T-2-126 was generated to look at potential steps toward improving the Material Readiness Posture of DoD (Short Title: R&M Study). This task order was structured to address the improvement of R&M and readiness through innovative program structuring and applications of new and advancing technology. Volume I summarizes the total study activity. Volume II integrates analysis relative to Volume III, program structuring aspects, and Volume IV, new and advancing technology aspects.

The objective of this study as defined by the task order is:

> "Identify and provide support for high payoff actions which the DoD can take to improve the military system design, development and support process so as to provide quantum improvement in R&M and readiness through innovative uses of advancing technology and program structure."

The scope of this study as defined by the task order is:

> To (1) identify high-payoff areas where the DoD could improve current system design, development program structure and system support policies, with the objective of enhancing peacetime availability of major weapons systems and the potential to make a rapid transition to high wartime activity rates, to sustain such rates and to do so with the most economical use of scarce resources possible, (2) assess the impact of advancing technology on the recommended approaches and guidelines, and (3) evaluate the potential and recommend strategies that might result in quantum increases in R&M or readiness through innovative uses of advancing technology.

The approach taken for the study was focused on producing meaningful <u>implementable</u> recommendations substantiated by quantitative data with implementation plans and vehicles to be provided where practical. To accomplish this, emphasis was placed upon the elucidation and integration of the expert knowledge and experience of engineers, developers, managers, testers and users involved with the complete acquisition cycle of weapons systems programs as well as upon supporting analysis. A search was conducted through major industrial companies, a director was selected and the following general plan was adopted.

<u>General Study Plan</u>

Vol. III • Select, analyze and review existing successful program

Vol. IV • Analyze and review related new and advanced technology

Vol. II (• Analyze and integrate review results
(• Develop, coordinate and refine new concepts

Vol. I • Present new concepts to DoD with implementation plan and recommendations for application.

The approach to implementing the plan was based on an executive council core group for organization, analysis, integration and continuity; making extensive use of working groups, heavy military and industry involvement and participation, and coordination and refinement through joint industry/service analysis and review. Overall study organization is shown in Fig. P-1.

The basic case study approach was to build a foundation for analysis and to analyze the front-end process of program structuring for ways to attain R&M, mature it, and improve it. Concurrency and resource implications were considered. Tools to be used to accomplish this were existing case study reports, new case studies

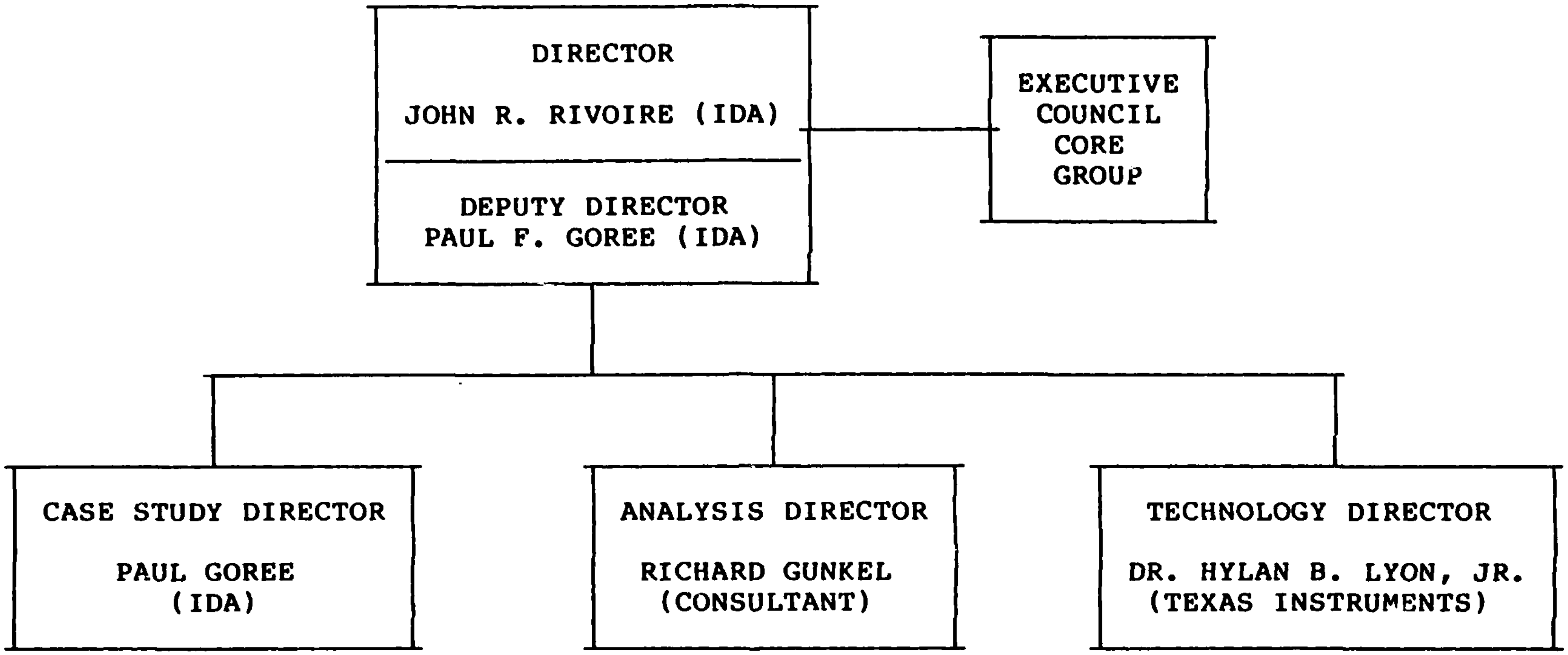


FIGURE P-1. Study Organization

conducted specifically to document quantitative data for cross-program analysis, and documents, presentations, and other available literature. In addition, focused studies for specific technology implications were conducted by individual technology working groups and documented in their respective reports. To accomplish the new case studies, the organization shown in Fig. P-2 was established.

In some areas where program documentation and records did not exist, the actual experience and judgement of those involved in the programs were captured in the case studies. Likewise, in the analysis process, the broad base of experience and judgement of the military/industry executive council members and other participants was vital to understanding and analyzing areas where specific detailed data were lacking.

This document records the program activities, details and findings of the Case Study Working Group for the specific program as indicated in Fig. P-2.

Without the detailed efforts, energies, patience and candidness of those intimately involved in the programs studied, this case study effort would not have been possible within the time and resources available.

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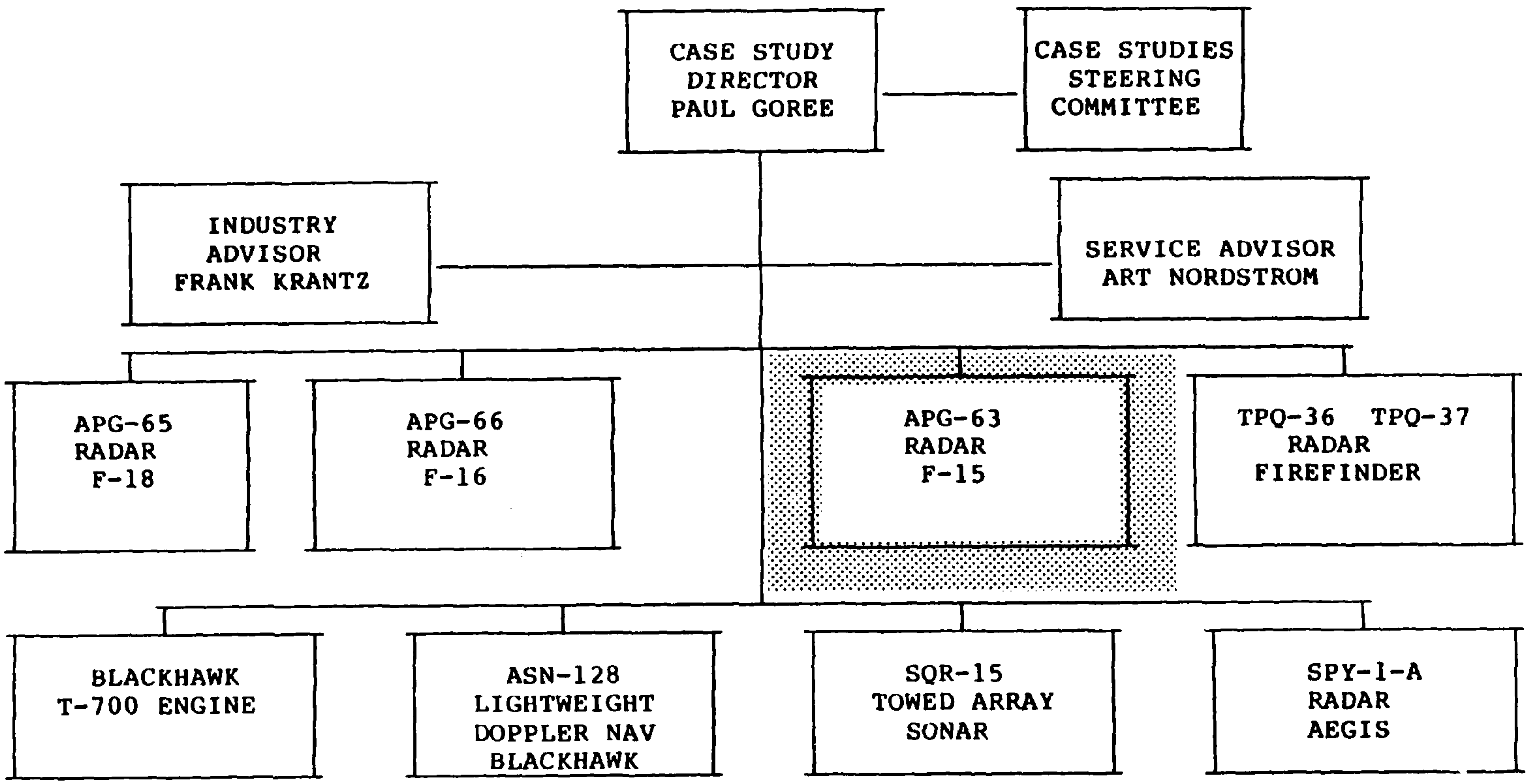

FIGURE P-2. Case Study Organization

F-15 AN/APG-63 RADAR

RELIABILITY & MAINTAINABILITY CASE STUDY

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FOREWORD

The Hughes AN/APG-63 was developed for the F-15 Eagle under the direction of the Avionics Engineering Division of McDonnell Aircraft Company and was designed and is being produced by the Radar Systems Group of Hughes Aircraft Company. A flyoff competition between Hughes Aircraft Co. and Westinghouse Radar Designs was held in mid-1970. A 50-flight evaluation program was conducted utilizing engineering development model (EDM) radar sets in WB-66 test aircraft. A full-scale development (FSD) contract go-ahead was issued to Hughes on 30 September 1970 and, as of the end of 1982, over 800 radar systems have been produced for the F-15 Eagle. This radar, which comprises about one-third of the F-15 avionics, is highly reliable and maintainable in comparison with previous radars having similar functions.

The reliability and maintainability requirements imposed on the program by the Air Force were, for the time period, extremely rigorous and challenging. This report describes briefly the APG-63 radar and tells how Hughes and McDonnell met the challenging requirements including the many factors that contributed to a successful R&M program. Valuable lessons learned and some recommendations are offered that may be of use to future programs.

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ABBREVIATIONS FOR F-15

ACM	Air Combat Maneuvering
ADTS	Avionic Depot Test System
AFB	Air Force Base
AFLC	Air Force Logistics Command
AFR	Air Force Regulation
AGE	Aerospace Ground Equipment
AGREE	Advisory Group on Reliability Electronic Equipment
AIS	Avionics Intermediate Shop
AMTI	Airborne Moving Target Indication
AOJ	Angle on Jam
ASP	Avionics Status Panel
ATG	Automatic Test Generation
BIT	Built-in-Test
BVR	Beyond Visual Range
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CC	Central Computer
CDRL	Contractor Data Requirements List
CFE	Contractor Furnished Equipment
CLEAR	Closed Loop Evaluation and Reporting
CM	Continuous Monitoring
CMUX	Computer MUX
cps	cycles per second
CTRL	Control
CWI	Continuous Wave Illumination
DAGC	Digital Automatic Gain Control
DBS	Doppler Beam Sharpening
DIGISAT	Digital Simulation and Test
DRO	Destructive Read Out
EAROM	Electrically Alterable Read Only Memory
ECCM	Electronic Counter Countermeasures
ECM	Electronic Countermeasures
ECP	Engineering Change Proposal
EDM	Engineering Development Model
EMC	Electromagnetic Compatibility
ESS	Environmental Stress Screening
ETI	Elapsed Time Indicator
FA	False Alarm
FET	Field Effects Transistor
FMC	Fully Mission Capable
FSD	Full Scale Development
GMT	Ground Moving Target
GMTD	Ground Moving Target Design
GMTI	Ground Moving Target Inhibit
GTWT	Gridded Traveling Wave Tube
HAC	Hughes Aircraft Company
HPRF	High Pulse Repetition Frequency
HRWS	High Range While Search
HOJ	Home on Jam
IC	Integrated Circuit
ICAP	Integrated Corrective Action Program
IDT	Integrated Dynamic Test
IF	Intermediate Frequency
IFF	Identification Friend or Foe
ILS	Integrated Logistic Support
IRAM	Integrated Reliability and Maintainability
LPRF	Low Pulse Repetition Frequency
LRU	Line Replaceable Unit
MAW	Minor Assist Work
McAIR	McDonnell Aircraft Company
MICP	Multiple Indicator Control Panel
MDC	McDonnell Douglas Cooperation

MFHBF	Mean Flight Hours Between Failure
MLC	Medium Lobe Clutter
MMH/FH	Maintenance Man Hours per Flight Hour
MMTR	Maintenance Man Hours to Repair
MPRF	Medium Pulse Repetition Frequency
MSI	Medium Scale Integration
MSIP	Multi-Stage Improvement Program
MTBD	Mean Time Between Demand
MTBF	Mean Time Between Failure
MTBM	Mean Time Between Maintenance
MTBMA	Mean Time Between Maintenance Action
MTTR	Mean Time to Repair
NCTR	Non-Cooperative Target Recognition
NDRO	Non-Destructive Read Out
NRTS	Not Repairable This Station
NORS	Not Operationally Ready for Spares
ORI	Operational Readiness Inspection
ORLA	Optimum Repair Level Analysis
PERS	Product Effectiveness Requirements Summary
PRF	Pulse Repetition Frequency
PRT	Production Reliability Test
PSP	Programmable Signal Processor
PWB	Printed Wiring Board
QPA	Quantity Per Application
RADC	Rome Air Development Center
RAM	Raid Assessment Mode
R&M	Reliability and Maintainability
RDP	Radar Data Processor
RF	Radio Frequency
RFP	Request for Proposal
RGS	Range Gate Stealer
ROM	Read Only Memory
RQT	Reliability Qualification Test
RSP	Radar Signal Processor
SEDS	Systems Effectiveness Data System (Air Force)
SPO	Systems Project Office
SRU	Shop Replaceable Unit
STT	Single Target Track
TAC	Tactical Air Command
TFG	Tactical Fighter Group
TFR	Trouble and Failure Report
TFS	Tactical Fighter Squadron
TFW	Tactical Fighter Wing
TF/TA	Terrain Following/Terrain Avoidance
TP	Test Procedure
TPP	Target Parameter Processor
TWS	Track While Scan
TWT	Traveling Wave Tube
VCO	Voltage Control Oscillator
VECP	Value Engineering Change Proposal
VGS	Velocity Gate Stealer
WAD	Work Authorization Delegation
WRALC	Warner-Robbins Air Logistics Center
WUC	Work Unit Code
XMTR	Transmitter

INTRODUCTION

INTRODUCTION

The Hughes APG-63 radar is the heart of the fire control system on the USAF F-15 airplane. This radar system comprises about 33 percent of the F-15 avionics.

This report describes briefly the APG-63 radar and then presents a historical road map to show how the program developed. Quantitative measures are defined which were the design criteria for a successful reliability/maintainability program. This is followed by a description of the many factors that contributed to the R&M program. The lessons learned during the course of the APG-63 program are summarized to provide insights and guidance for later programs.

MISSION NEEDS

MISSION NEEDS

The F-15 Eagle was designed as a high-performance, supersonic, all-weather air-superiority fighter. Its primary mission is to maintain control of the airways against all threats. Because the threats consist of several different types of aircraft, the Eagle must be able to fight in different arenas. It has to out-maneuver the opponent in a dogfight, it requires beyond visual range to counter enemy armament, and it must be able to escort other aircraft and protect them from attack in both defensive and offensive roles. For all these roles, the Eagle carries both long-range Sparrow radar missiles, shorter-range heat-seeking Sidewinder missiles, and an internally wing-mounted 20mm gun. This air-superiority mission dictated the radar requirements. Long-range detection and tracking of the enemy was required to allow the F-15 to control the engagement. Since earth-hugging targets had to be found and attacked, the radar had to solve the nose/tail hemisphere ground clutter detection problem. The close-in rapid dogfight air combat mission dictated the development of fast automatic target acquisition modes. So that F-15 pilots flying in formation can distinguish individual targets in enemy formations and press the attack on separate close-flying targets, a high-resolution radar raid assessment capability was also required. In addition, an integral IFF system which can be used to identify friendly from enemy aircraft was required.

F-15 MISSION NEEDS

- AIR SUPERIORITY FIGHTER

ADVANCED RADAR

- LONG RANGE
- ALL-ASPECT LOOK-DOWN CAPABILITY
- AUTOMATIC TARGET ACQUISITION
- RAID ASSESSMENT
- IFF TARGET IDENTIFICATION
- HIGH RELIABILITY/MAINTAINABILITY

4 LONG-RANGE SHOOT-DOWN AIM-7F SPARROW RADAR MISSILES

4 SHORT-RANGE HEAT-SEEKER AIM-9L/M SIDEWINDER MISSILES

20MM CANNON WITH 940 ROUNDS AMMUNITION

RADAR PERFORMANCE

A generalized radar range equation (such as in Skolnik's Radar Handbook) is used to compare the detection performance of various radar designs. The radar equation states that if long ranges are required, the transmitter power must be large, the radiated energy must be concentrated into a narrow beam (high transmitting antenna gain) and the received echo energy must be collected with a large aperture antenna (also synonymous with high gain). A comparison of three different designed radars can be seen in the accompanying chart. The F-15 radar long-range capability was specified to take advantage of beyond visual range attacks and to provide multiple positions of advantage on enemy targets.

LPRF = Low Pulse Repetition Frequency

MPRF = Medium Pulse Repetition Frequency

HRWS = High Range While Search

All Aircraft in 2 Bar Wide Search Pattern ($\approx$ Equal Altitude Coverage at Detection Range)

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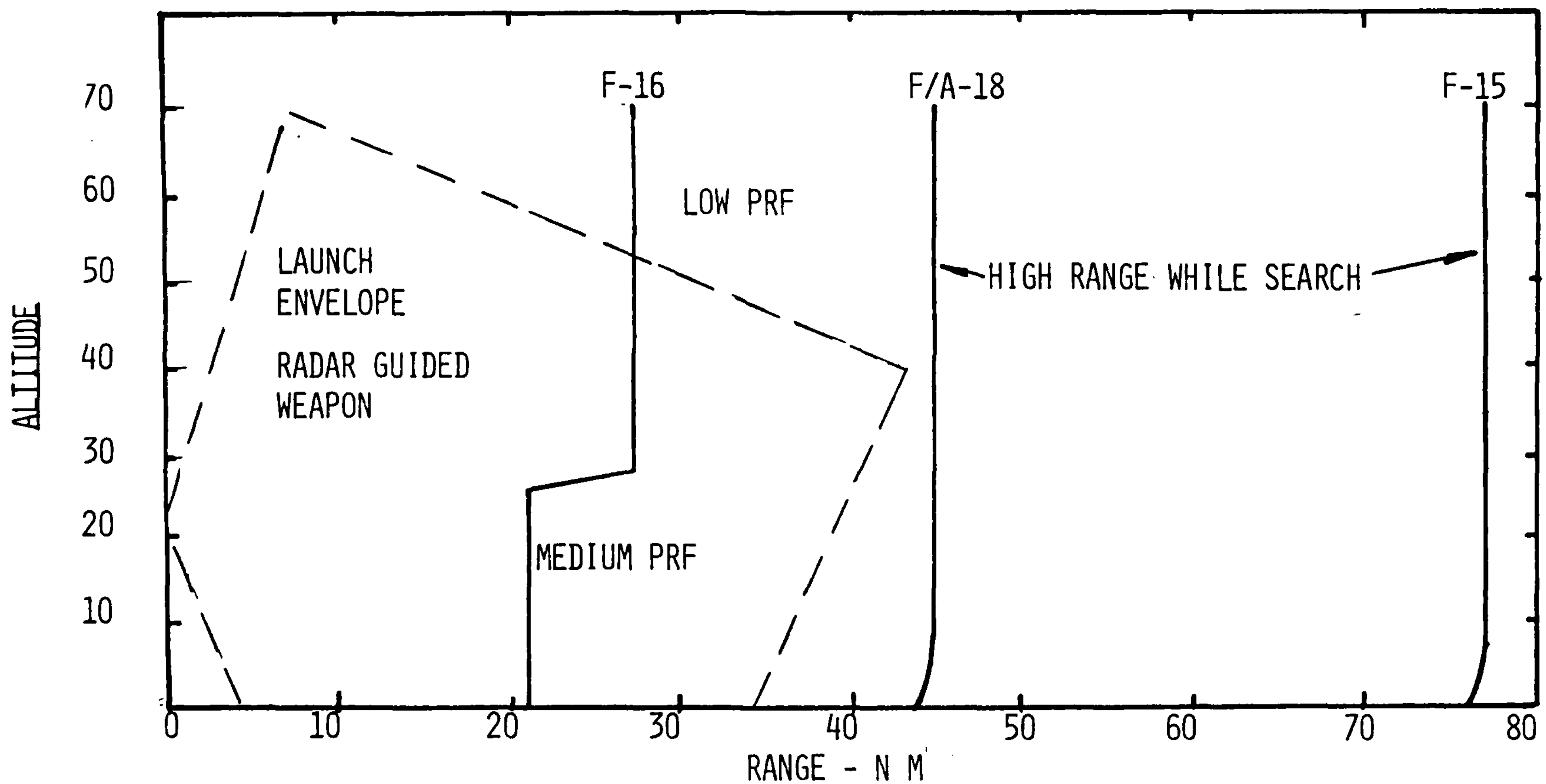
RADAR DETECTION RANGE/MISSILE ENVELOPE
(MEDIUM SIZE TARGET)



BASED ON GENERALIZED RADAR RANGE EQUATION (SUCH AS IN SKOLNIK RADAR HDBK)

SYSTEM DESCRIPTION

- TECHNOLOGY CONTRIBUTIONS

A number of electronic technologies became available in the late 1960s that allowed the formulation of a radar system that provided detection and tracking over all aspects of look-down ground clutter. This radar, the APG-63, is a high-power, coherent pulse doppler system that combined the proven long-range head-on look-down detection capability of a high PRF system with a new Airborne Moving Target Indication (AMTI) waveform in the medium PRF region for shorter-range, all-aspect look-down capability necessary for air combat maneuvering. The design flexibility of diverse waveforms, and high and medium PRFs, was made available through the development of the shadow grid traveling wave tube transmitters. The low antenna sidelobe levels that are critical to the new medium PRF AMTI mechanization were made possible by precise control of planar array radiation distributions.

- APPLICATION OF DIGITAL CONTROL AND SIGNAL PROCESSING TECHNIQUES

The development of all solid state digital signal processing was the most significant event in this radar evolution, literally revolutionizing radar design concepts and allowing the mechanization of range-gated pulse doppler systems within the size and weight limitations of fighter aircraft. Application of a digital computer to radar control functions enabled new pilot aids for one-man operability. A newly-developed digital multiplex bus (MDC Report H009) simplified the radar interface with other avionics systems. The continuing progress in digital technology has allowed the radar to grow both in performance and reliability.

A Programmable Signal Processor (PSP) was introduced in 1980, and, besides adding previously hard-wired digital processing functions to software, it provided higher reliability through the use of higher density 4K RAM ICs. A 16K-word ferrite-core general-purpose program digital computer was initially used to provide automatic control of all radar modes. This included all Built-In-Test routines and BIT test result storage in a coded matrix that is made available for playback for the maintenance crew.

- APPLICATION OF DIGITAL CONTROL AND SIGNAL PROCESSING TECHNIQUES (continued)

Availability of solid state Electrically Alterable Read Only Memory (EAROM) devices allowed the introduction of a 24K-word Solid State Computer in 1977 as a value change program cost savings. This computer had the growth capability to 96K-word capacity by module addition. In 1980, the increased storage was used in conjunction with the PSP.

- DECREASED PARTS COUNT

The application of later technology has allowed the radar to reach the present part count of 18,800, down some 4,000 from the R&D program.

F-15 APG-63 AIR SUPERIORITY RADAR

- ADVANCED RADAR DESIGN

⇩

- BUILDING BLOCKS

  - DIGITAL CONTROL AND MULTIPLEX DATA BUS
  - DIGITAL SIGNAL PROCESSOR
  - HIGH POWER GTWT TRANSMITTER
  - HIGH GAIN/LOW SIDELOBE PLANAR ARRAY ANTENNA

⇩

- DEVELOPED NEW CONCEPTS

  - MEDIUM PRF ACM
  - INTERLEAVED HIGH PRF/MEDIUM PRF
  - PSP WITH RAID ASSESSMENT

⇩

- FIRST LONG-RANGE, ALL-ASPECT, ALL-WEATHER, LOOK-DOWN/SHOOT-DOWN COHERENT PULSE DOPPLER RADAR

F-15 APG-63 RADAR SYSTEM OVERVIEW

(1) The all-aspect, all-weather, look-down/shoot-down capability has resulted in the F-15 attacking and destroying objects flying as low as 500 feet. Ground clutter is eliminated. All-altitude and all-aspect capability provides for radar operation at long or short ranges, in nose-on or tail attack modes. F-15s have destroyed simulated MiG-25s flying at Mach 2.7 at altitudes up to 71,000 feet.

(2) This is the first production radar to use medium pulse doppler as well as high PRF.

(3) F-15Cs/Ds are the first operational tactical fighters in the free world equipped with radars incorporating a digital programmable signal processor. These PSPs provide the potential to respond to new threats and to accommodate improved modes and weapons through software reprogramming rather than by extensive hardware retrofit. F-18 Radars now have this capability.

(4) A digital computer controls most radar operations, leaving the pilot free to concentrate on the attack. Automatic target acquisition and lock-on is provided.

(5) An engineering development model (EDM) go-ahead was initiated on 4 November 1968 (over one year before the F-15 airframe contract was awarded) and this culminated in a Hughes/Westinghouse fly-off during the period 1 July through 1 September 1970. An FSD go-ahead was awarded to Hughes on 30 September 1970.

(6) The radar has a demonstrated detection range of more than 100 nautical miles (161 km) against small size targets.

(7) Built-in test capability automatically isolates faults to the affected unit. Units are replaced with no adjustments or harmonization required.

F-15 RADAR (AN/APG-63) OVERIVEW

1ST

- ✓ ALL-ASPECT, ALL-WEATHER, LOOK-DOWN/SHOOT-DOWN, COHERENT PULSE DOPPLER RADAR
- ✓ PRODUCTION RADAR TO USE MEDIUM PULSE DOPPLER AS WELL AS HIGH PRF
- ✓ OPERATIONALLY DEPLOYED RADAR TO USE PROGRAMMABLE SIGNAL PROCESSOR
- ✓ PRODUCTION RADAR TO USE DIGITAL PROCESSING
- ✓ FSD RADAR PROGRAM AWARD BASED ON COMPETITIVE FLY-OFF
- ✓ LONG-RANGE RADAR AGAINST SMALL TARGETS
- ✓ RADAR THAT COULD BE MAINTAINED WITHOUT FLIGHT-LINE AGE

SYSTEM DESCRIPTION

The AN/APG-63 radar for the U.S. Air Force's F-15 Eagle is a flexible, all-weather, multimode radar designed to conform with the single pilot concept.

The radar combines long range acquisition and attack capabilities with automatic features that provide pilots the instant information and computations needed in close-in aerial combat.

It employs a gridded traveling-wave tube transmitter, digital Doppler signal processing, and digital mode/data management. These features permit operation over a wide range of pulse repetition frequencies (PRF), pulse widths and processing modes. The antenna is an X-band planar array type, gimbaled in three axes to maintain lock-on during rapid roll maneuvers.

The APG-63 has multiple operating modes, including track-while-scan, high/medium PRF range-while-search, high PRF velocity search, single target track, weapons delivery for Sparrow and Sidewinder missiles and 20mm cannon, real beam and Doppler beam sharpened ground mapping, air-to-surface ranging, precision velocity update, and fixed and moving ground target track.

All APG-63s manufactured since late 1979 have incorporated programmable signal processors (PSPs), high-speed digital computers which provide the ability to respond to new tactics or to accommodate improved modes and weapons through software reprogramming rather than by hardware retrofit. The APG-63 was the first deployed airborne radar in the free world to utilize a programmable signal processor.

<u>F-15 WEAPON SYSTEM - RADAR</u>

- ONLY AIR FORCE FIGHTER WITH LONG-RANGE ALL-ASPECT (HEAD-ON & TAIL-ON) LOOK-DOWN, SHOOT-DOWN CAPABILITY

- FIRST U.S. FIGHTER WITH AUTO-ACQUISITION (SUPERSEARCH MODE)

  - <u>ONLY</u> FIGHTER WITH THIS CAPABILITY 500 FT TO 10 NMI

- ONLY FIGHTER WITH INTEGRATED IFF SYSTEM

  - IFF AT SAME RANGE AS RADAR DETECTION
  - CORRELATES IFF AND RADAR RETURNS AND DISTINGUISHES ON DISPLAY
  - IFF IN <u>ALL</u> MODES

- ONLY FIGHTER WITH RAID-ASSESSMENT MODE TO 40 NMI

  - RESOLVE TARGETS IN 1/10 BEAMWIDTH

- PROVEN ECCM CAPABILITY

  - OVER 200 FLIGHTS - 400 PASSES
  - THE STANDARD USED TO DEVELOP NEW JAMMERS
  - THE SURROGATE ECCM THREAT FOR NEW ECM DEVELOPMENT

F-15 APG-63 RADAR MODES

	PRIMARY SEARCH/ TRACK MODES	AUTO MODES	ECCM MODES	AIR-TO-GROUND MODES
BASELINE MODES	VELOCITY SEARCH	AUTO GUN	AOJ (ANGLE ON JAM)	AIR-TO-GROUND RANGING
	LONG RANGE SEARCH	SUPERSEARCH	HOJ (HOME ON JAM)	PULSE GROUND MAPPING
	SHORT RANGE SEARCH	VERTICAL SCAN	VGS/RGS	DOPPLER UPDATE
	PULSE SEARCH	BORESIGHT	SNIFF	BEACON
			MANUAL TRACK	
			6 PILOT SELECTABLE RF CHANNELS	
PSP MODES	RAID ASSESSMENT MODE	IMPROVED SUPERSEARCH	IMPROVED VGS	DOPPLER BEAM SHARPENING GROUND MAPPING
	IMPROVED PULSE SEARCH			
	INCREASED GMT INHIBIT			

GMT = GROUND MOVING TARGET

VGS = VELOCITY GATE STEALER

RGS = RATE GATE STEALER

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RADAR MISSION AND DESIGN

MISSION

- LONG-RANGE DETECTION AND TRACKING OF SMALL TARGETS IN PRESENCE OF STRONG CLUTTER
- TARGET ILLUMINATION FOR BVR AIM-7F MISSILE AT MAXIMUM LAUNCH RANGE
- ACM QUICK REACTION AUTOMATIC TARGET ACQUISITION
- ELECTRONIC COUNTER-COUNTERMEASURES

DESIGN

- DETECTION PERFORMANCE PRINCIPALLY RELATED TO TRANSMITTED POWER AND ANTENNA GAIN

  RF POWER = HIGH WATTS (AVG)

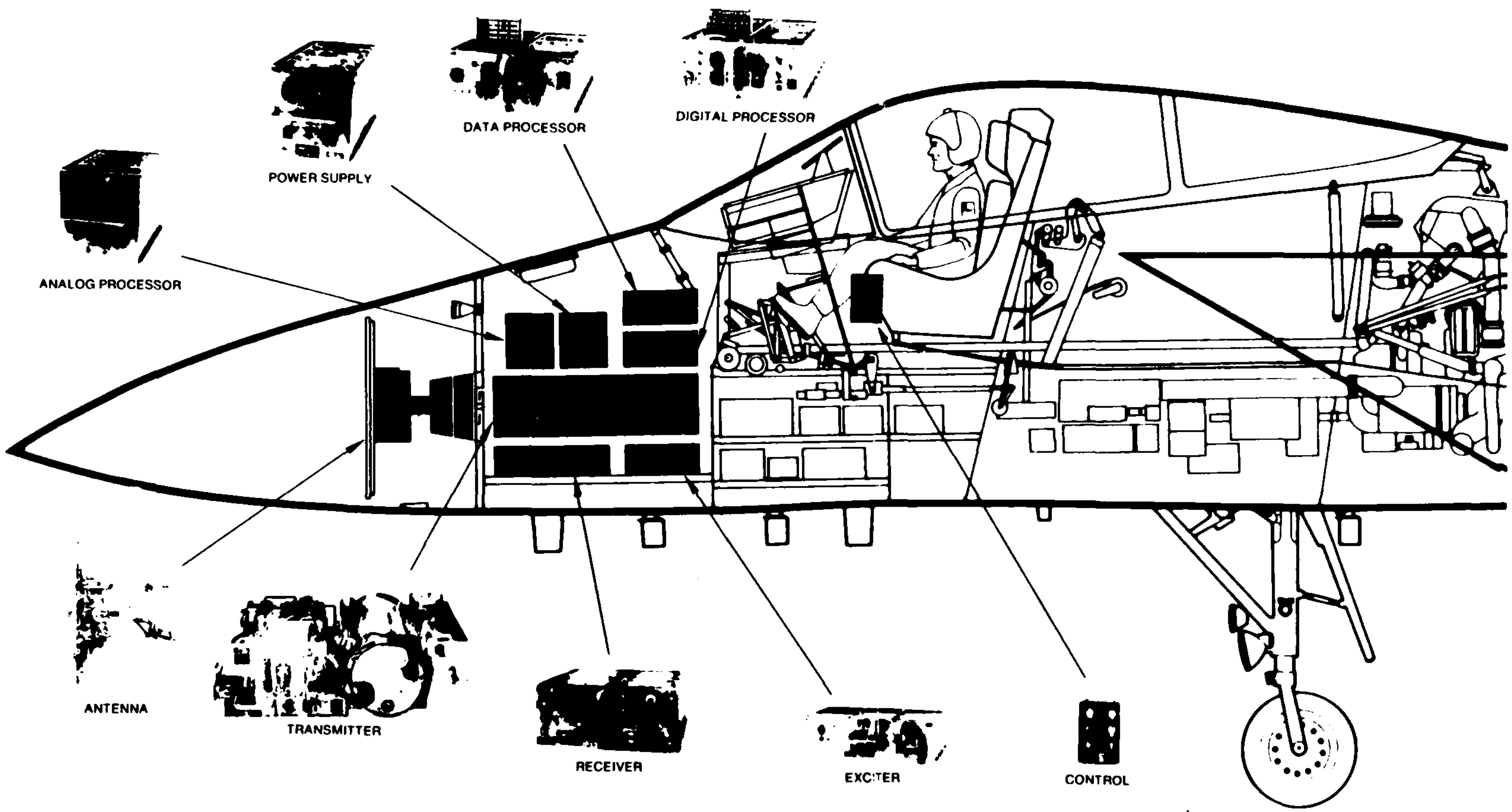
  ANTENNA SIZE = 36" DIA

- DUAL WAVEFORM OF HIGH PRF AND MEDIUM PRF MODES

  HIGH PRF - LONG-RANGE DETECTION AND AIM-7F TARGET ILLUMINATION

  MEDIUM PRF - SHORT-RANGE AUTO ACQUISITION

F-15 APG-63 RADAR LRUs



F-15C/D APG-63 RADAR LRUs

TITLE	HAC P/N	WEIGHT	SALIENT FEATURES
ANTENNA	031	105 LBS	36" PLANAR ARRAY ANTENNA
TRANSMITTER	011	175 LBS	HI AVERAGE PWR WATTS, LO PK PWR PD TRANSMISSION
RF OSCILLATOR	001	26.4 LBS	STABLE LO NOISE SIGNAL GENERATION FOR XMTR CONTROL
RECEIVER	022	24.0 LBS	AMPLIFY AND DOWN CONVERT HI FREQ SIGNAL RETURNS TO IF FREQ FOR SIGNAL PROCESSING
ANALOG PROCESSOR	039	27.2 LBS	CLUTTER REJECTION, PREPROCESSING, AND CONVERSION OF SIGNALS INTO DIGITAL FORM
DIGITAL PROCESSOR	042	59.4 LBS	DOPPLER PROCESSING, RANGE RESOLVING, DIGITAL SCAN CONVERSION AND IFF CONTROL AND CORRELATION
DATA PROCESSOR	081	47.2 LBS	GENERAL PURPOSE COMPUTER, PERFORMS ALL INTERNAL MANAGEMENT & CONTROL FUNCTIONS, PRIME INTERFACE UNIT
RADAR SET CONTROL	541	3.4 LBS	CONTROL PANEL TO OPERATE RADAR SET
POWER SUPPLY	610	40.5 LBS	CONVERTS PRIME A/C POWER INTO VARIOUS POWER FORMS FOR USE BY RADAR LRUs
MISCELLANEOUS (FLOOD ANT., WAVEGUIDE, ETC.)		7.7 LBS	
TOTAL		515.8 LBS	

46A/1-6

F-15C/D APG-63 RADAR SYSTEM PARAMETERS

							DISSIPATION (WATTS)	
	WT (LB)	VOL (FT^3)	ALLOCATED MTBF (HOURS)	PARTS	IC's	MFHBF(3) (APR-SEP 82)	AIR/AMBIENT COOLED	LIQUID COOLED
ANT(031)	105	N/A	349	162	--	106	325 (2)	
TRANS(011)	175	3.09	293	1,336	93	142	237 (1)	8380
RF OSC(001)	26.4	1.00	1,094	691	15	437	120	
RECEIV(022)	24	0.68	1,000	527	20	310	269	
ANALOG P.(039)	27.2	0.87	507	1,885	201	151	303	
DIGITAL P.(042)	59.4	1.17	432	7,194	4,645	420	1,575	
DATA P.(081)	47.2	1.05	374	6,002	2,117	186	788	
SET CTRL(541)	3.4	0.07	6,211	38	2	3,690	15 (2)	
PWR SUPPLY(610)	40.5	1.07	797	995	64	261	654	
MISC. (WAVE GUIDES,ETC.)	7.7	N/A	10,000	--	--	--	N/A	
TOTAL	515.8	9.00	60	18,830	7,157*	22.4	4286	8380

NOTES:

(1) AIR COOLED: 237 WATTS; LIQUID COOLED: 8380 WATTS INCLUDING DUMMY LOAD.

(2) AMBIENT COOLED

(3) COMPLETE RELIABILITY HISTORY FOR A/B AND C/D RADARS CAN BE FOUND AT PAGES IIE-82-93

* INCLUDES 122 HYBRIDS

46A/1-54

MEMORY LOADING

- Existing F-15 C/D aircraft have radars with 24 Bit words so that 94,335 x 24 = 2.26 Megabit capability.

- THE MSIP (Multi-Stage-Improvement-Program) radars for F-15 (E) will have 220,800 x 16 Bits or a 3.53 Megabit capability.

- The dual-role fighter F-15 will have an even larger memory; 348,622 x 16 Bit or 5.57 Megabit capability.

F-15 APG-63 MEMORY LOADING

	CONSTANTS	ORDERS (INSTRUCTIONS)	WORDS (MEMORY)
PSP			
A/A	1,516	22,108	45,732
A/G	416	3,428	7,272
BIT	460	2,472	5,404
MASTER EXEC. LOADER	512	784	2,080
COMMON (EITHER A/A OR A/G)	--	648	2,592
TOTAL	2,904	29,440	63,080
RDP			
A/A	527	15,572	14,737
A/G	84	3,823	3,545
BIT	210	4,905	4,458
MASTER EXEC. LOADER	597	2,785	2,530
COMMON	194	6,574	5,985
TOTAL	1,612	33,659	31,255
EAROM			
PSP	2,904	29,440	63,080
RDP	1,612	33,659	31,255
TOTAL	4,516	63,099	94,335

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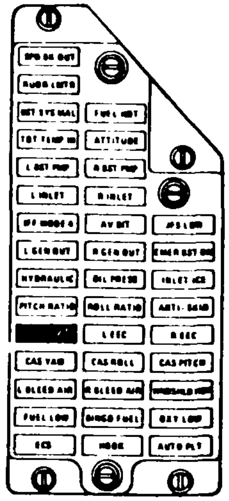
RADAR FAULT ISOLATION USING BIT

The objectives of the BIT test are to detect a radar system failure and to isolate that failure to a faulty LRU. To accomplish the fault detection and isolation, BIT employs both hardware and software. The software function is scheduling tests, configuring the radar system for tests and evaluating test results. BIT hardware provides the various test circuits and signals which are controlled by the software. BIT tests are designed to exercise and analyze the radar set as it would normally be used. Continuous BIT monitors and records all radar faults into the BIT matrix. Airborne initiated BIT is used to detect faults in flight. The pilot is alerted to a radar system fault by the Caution Light Panel (1). He performs initiated BIT to confirm the fault and can observe the fault light on the BIT Control Panel (2). Ground initiated BIT is used by the maintenance technician.

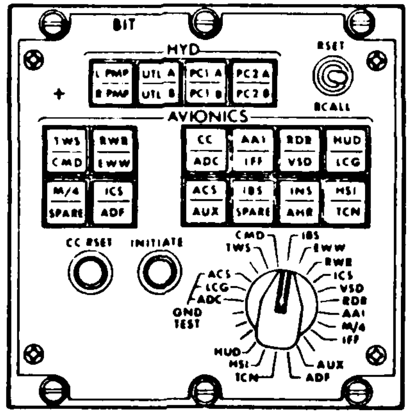
- Perform initiated BIT in STBY mode to confirm pilot squawk. Radar faults that were detected during flight by continuous monitor BIT are recorded in the BIT matrix for this test.
- Perform initiated BIT and operational tests. Observe fault indications on the Multiple Indicator Control Panel (MICP) (3) and the BIT Control Panel. Use the Radar BIT Matrix to interpret failure code readouts to determine faulty LRU.
- Observe Avionics Status Panel (ASP) (4) in the nose wheel well.

- Observe for latched fault indicators on each of the Radar System LRUs mounted inside the Radar Equipment Bay (5).

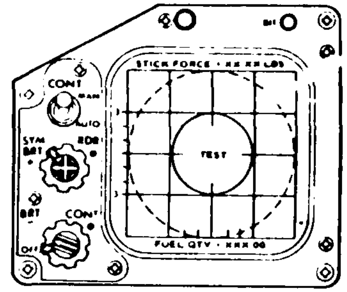
F-15 FAULT ISOLATION



(1) CAUTION LIGHT PANEL

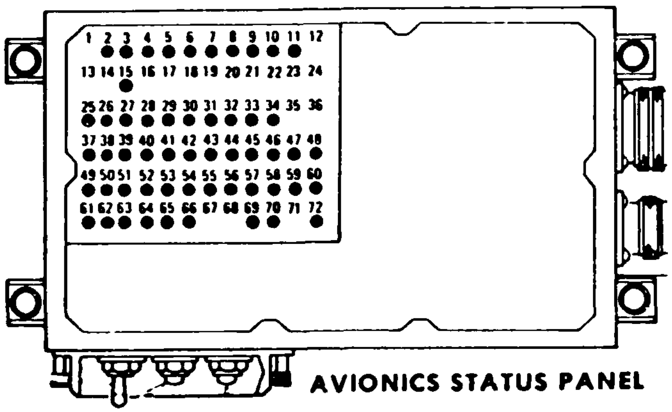


(2) BIT CONTROL PANEL



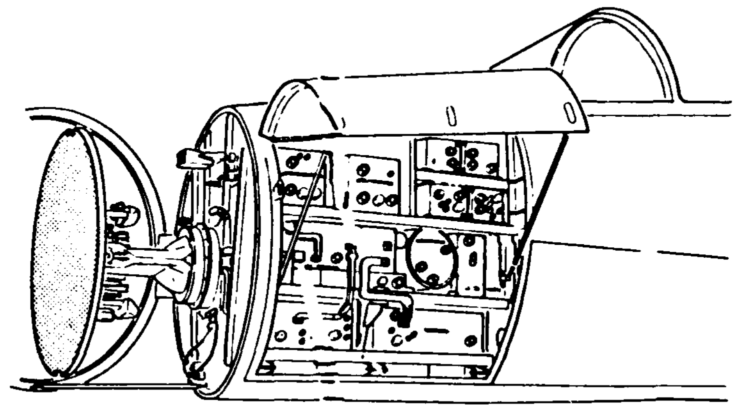
MULTIPLE INDICATOR CONTROL PANEL (MICP)

(3) MICP



AVIONICS STATUS PANEL

(4) ASP

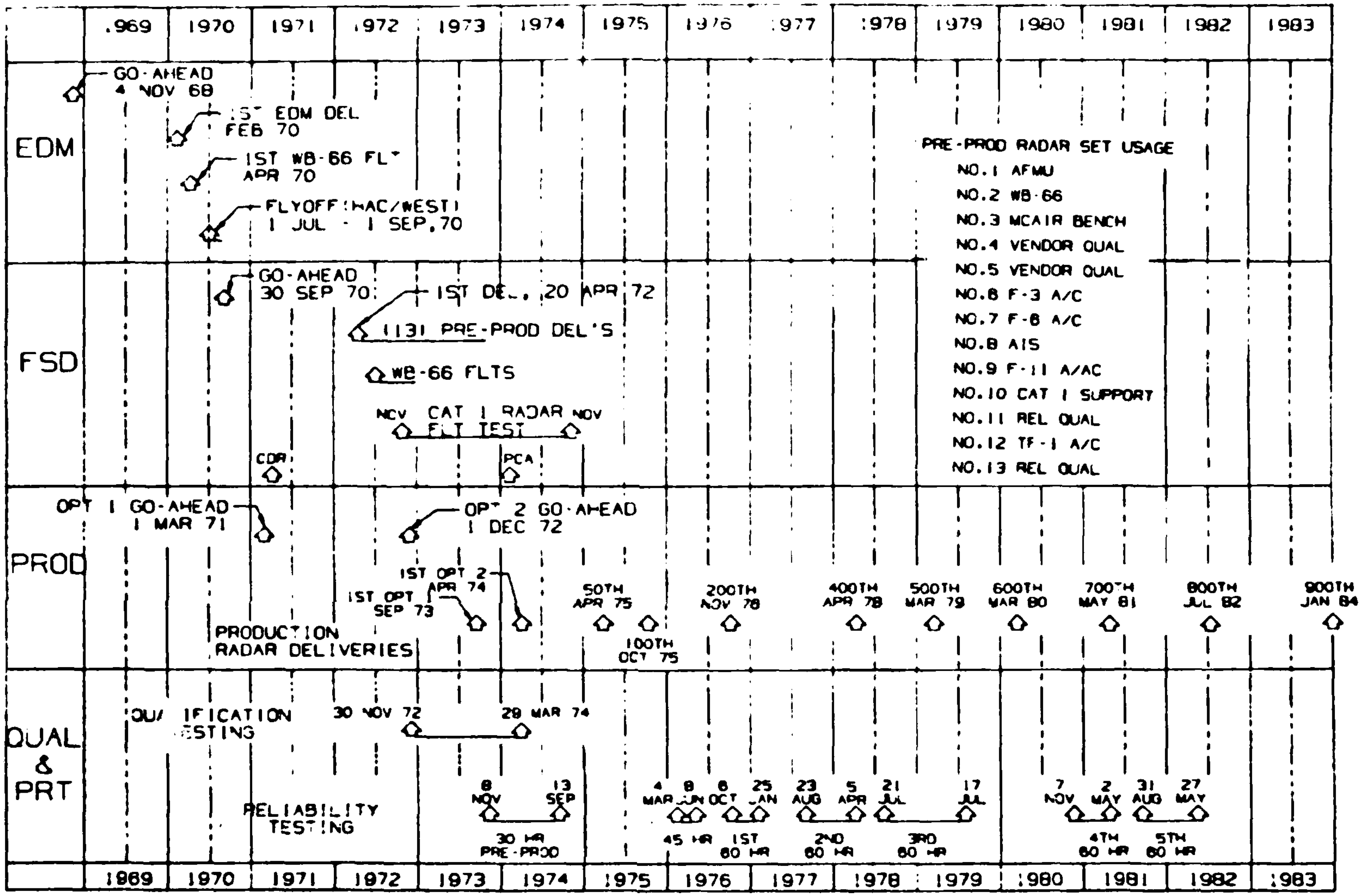


(5) RADAR EQUIPMENT BAY

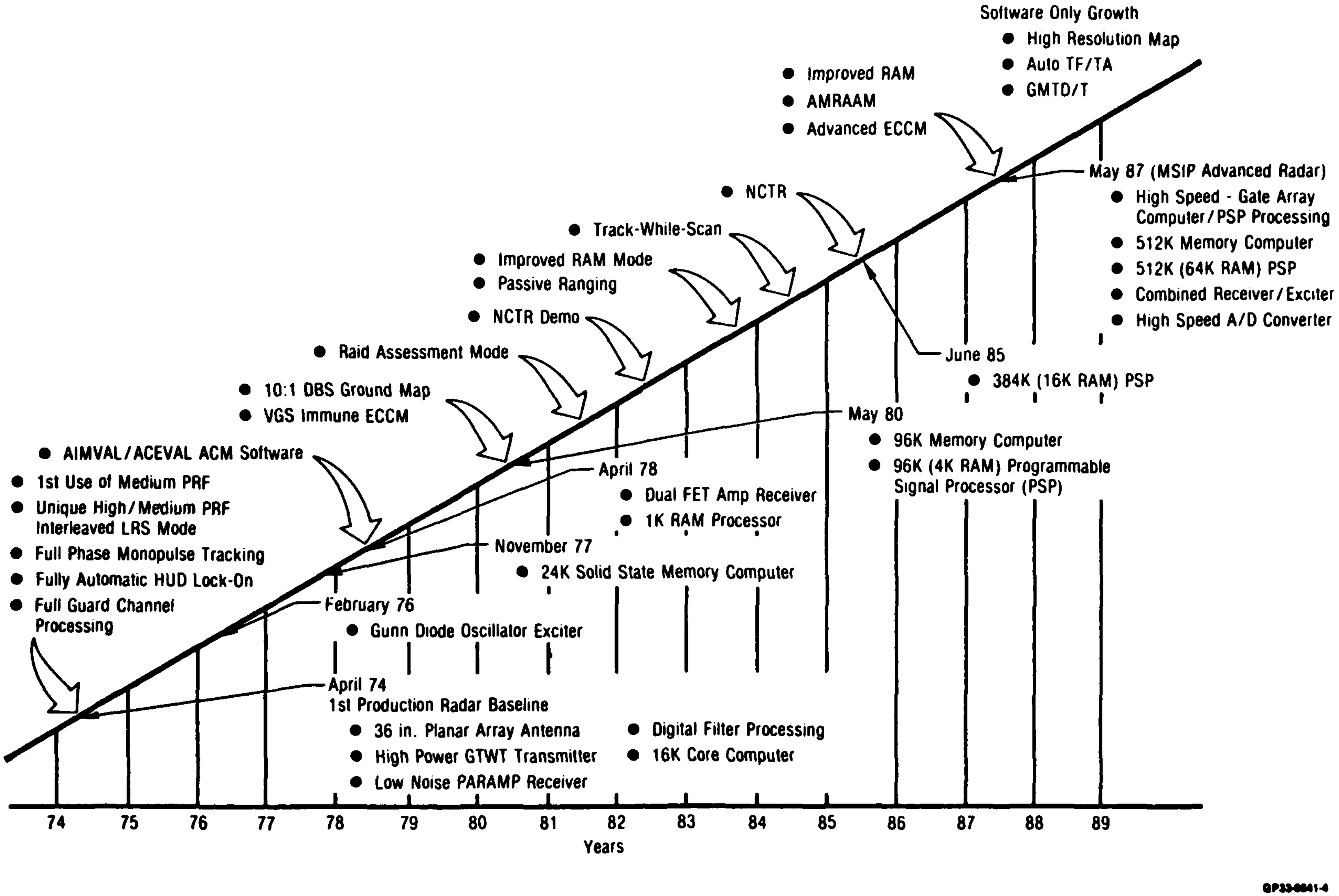
PROGRAM SUMMARY

F-15 RADAR HISTORICAL EVENTS

REVISION A



F-15 Radar Technology Evolution



PROGRAM

The emphasis on high reliability and ease of maintenance was clearly set forth in Air Force Request for Proposals (RFPs) provided to industry. This was recognized by both the Hughes (HAC) and McDonnell Aircraft (MCAIR) organizations. Early in the program both companies identified responsible management team members including reliability, maintainability, design, test, etc., and identified the needed organizational structure. As a result, requirements were understood, responsibilities assigned, and an avionics integration team established. Periodic Technical Coordination Meetings (TCMs) were held between Hughes and McDonnell with Air Force representatives often in attendance. McDonnell Aircraft's Closed Loop Evaluation and Reporting (CLEAR) and Hughes' Trouble and Failure Report (TFR) systems were utilized to assist in identifying problems that were either resolved at the working level or elevated to the "Eagle Watch" meetings run by the F-15 program manager for action when required.

RELIABILITY

For the first time in a major aircraft weapon system procurement, reliability growth was required for the aircraft, radar, and numerous subsystems and equipment. Radar requirements were 30 hrs MTBF for preproduction units, 45 hrs at delivery of the 60th production unit, and 60 hours MTBF at delivery of the 120th production unit. MIL-STD-781B testing in accordance with Test Plan III (10.3 x MTBF = max test time) and Level F (modified) -54°C/ -40°C to +71°C was specified. Parts standardization, including participation in the Parts

Control Board, derating and Hi-Rel parts were made part of the HAC contract as it was between the Air Force and MCAIR. HAC responded with a proposal based on their studies, which recommended four levels of screening (parts, module, LRU and system). Applicable tasks from MIL-STD-785 were specified, such as predictions, thermal analysis, failure mode and effects analysis and failure reporting. HAC and MCAIR participated in Category I and II testing, in addition to early Luke and Langley Air Force Base operations, so that radar MTBFs could be measured and reported on for corrective action on identified problems.

RADAR PROGRAM SUMMARY

PROGRAM:

- CFE CONTRACT
- STRONG AVIONICS INTEGRATION TEAM
- PROBLEM IDENTIFICATION AND RESOLUTION
  - ✓ INTEGRATED CORRECTIVE ACTION PROGRAM (ICAP)--STARTED AFTER PRODUCTION
  - ✓ CLEAR--USED THROUGHOUT THE PROGRAM
  - ✓ EAGLE WATCH
- TECHNICAL COORDINATION MEETINGS

RELIABILITY:

- RELIABILITY GROWTH REQUIRED
- PARTS STANDARDIZATION REQUIRED (DERATING, HI-REL PARTS)
- FOUR LEVELS OF SCREENING (PARTS, MODULE, LRU & SYSTEM)
- REL PREDICTIONS, THERMAL ANALYSIS, FAILURE REPORTING
- MEASURED FIELD AND MIL-STD-781 TESTS

MAINTENANCE:

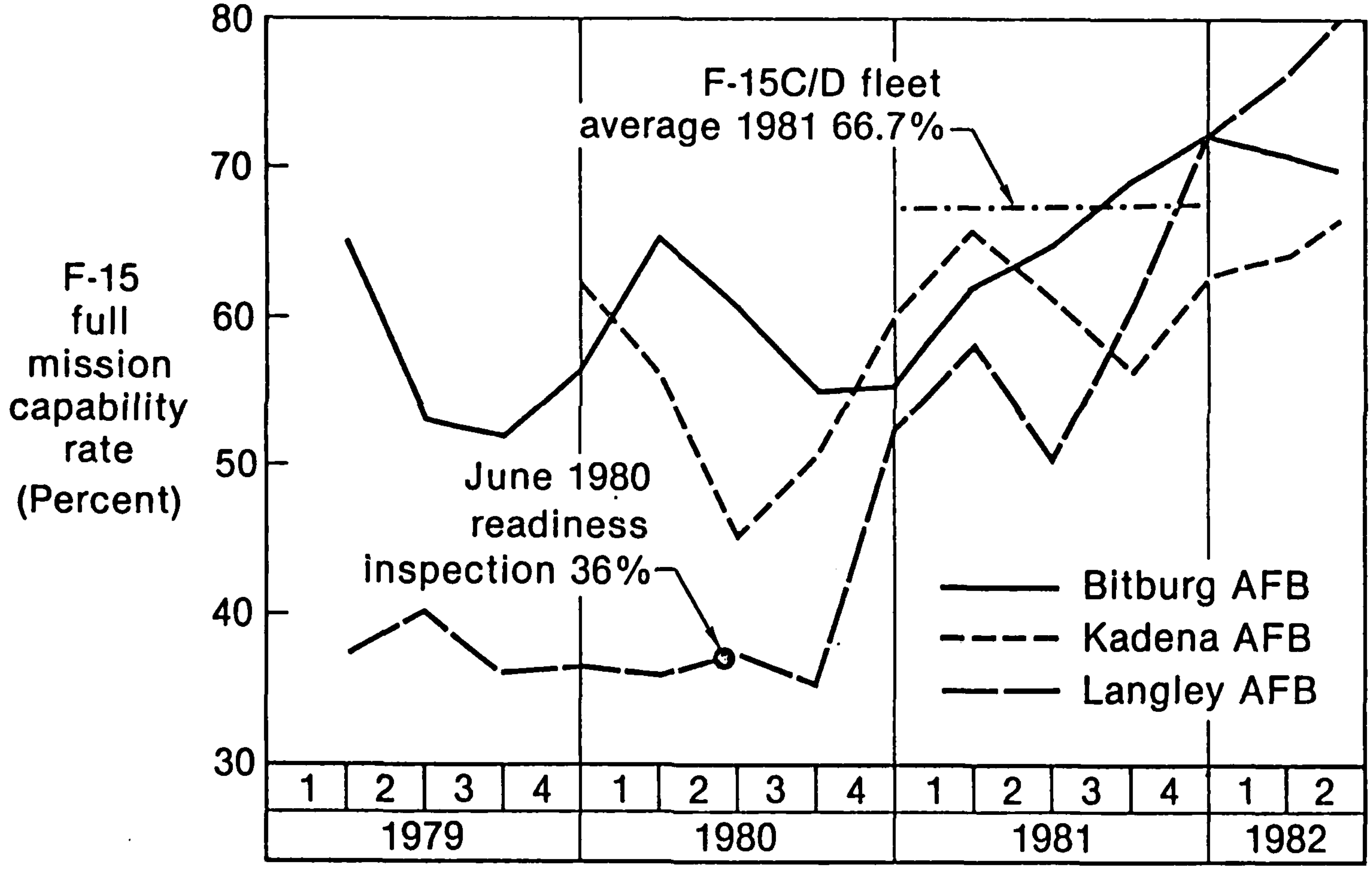
- NO FLIGHT LINE (ORGANIZATIONAL) TEST EQUIPMENT
- NO LRU HARMONIZATION REQUIRED
- BIT-FAULT DETECTION/LRU ISOLATION
- NO SCHEDULED MAINTENANCE

46/1-10

MEASURES OF SUCCESS

46A/6-5

F-15 Readiness Trends



USAF fleet average in 1981 – 53.4%
F-15C/D, A10, F-15A/B, F-5E, F-16, A-7, F-111F, RF-4C, F-4E, F-4D, F-111D

SOURCE: AFLC D056 REPORTING SYSTEM   PREPARED BY: AF/LEYYC

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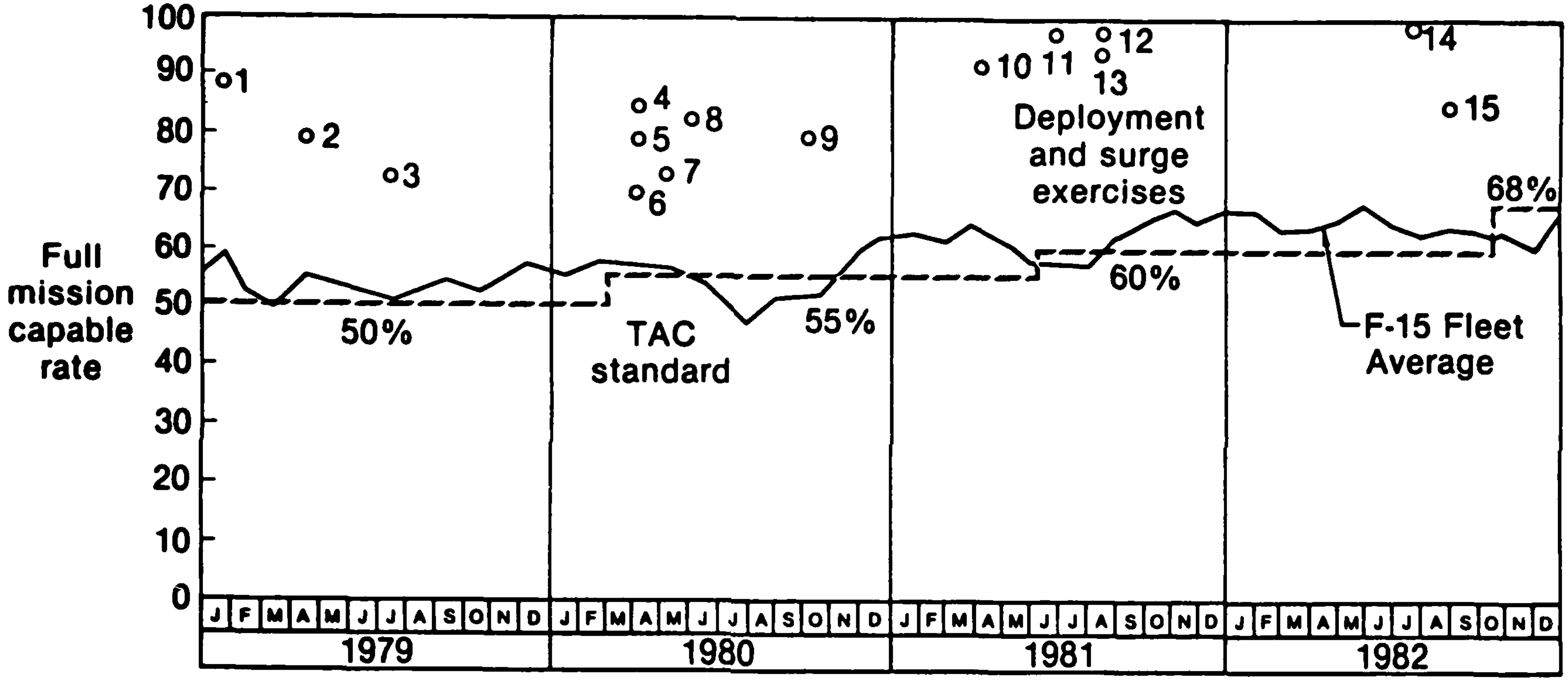
GP21-0023-11

F-15 BLENDS CAPABILITY AND READINESS

The F-15 has demonstrated the capability to exceed the TAC standard established for the fully mission capable rate.

Experience has shown that during normal operations, aircraft are generally maintained to meet the TAC standard. However, whenever higher levels of readiness were required, they were achieved as shown by the various deployments, surges, and exercises for the F-15 aircraft.

F-15 Capability and Readiness



1. Prized Eagle deployment
2. ORI 49 TFW
3. Maximum push 32 TFS
4. Team spirit 18 TFG
5. Maple flag 1 TFW
6. Eagle thrust 80-3 1 TFW
7. Kadena surge 18 TFG
8. Red flag 80-4 49 TFW
9. Coronet Eagle
10. Team spirit 1 TFW
11. Coronet anchor 1 TFW
12. Coronet sloop 49 TFW
13. Coronet compass 49 TFW
14. Team spirit 18 TFW
15. Langley ORI

——— Operational F-15 Total Fleet Average

------ TAC Standard for F-15

o Percentage for FMC for Deployments 1 through 15

GP21-0847-6

CORONET EAGLE

Coronet Eagle was to demonstrate F-15 ability to deploy to Europe, regenerate the aircraft within a specified time, fly sortie surges in excess of planned wartime tasking and to examine the logistics impact of this flying level.

Sixteen F-15A and two F-15B Eagles of the 58th TFS, 33 TFW flew nonstop from Eglin AFB to Bremgarten AB. The aircraft made five inflight refuelings each and flew 4,500 miles in an average of 9.3 hours. While at Bremgarten, the Eagles flew a variety of missions including:

Orientation
Air Combat Tactics
Basic Fighter Maneuvers
Cross Country
Functional Check Flight
Instrument Proficiency
Intercept

During the deployment, the Eagles achieved or exceeded all goals. To accomplish this, a total combat package of personnel, aircraft, engines, support equipment, and supply support was assembled to demonstrate a wartime capability.

CORONET EAGLE
DEPLOYABILITY/AVAILABILITY RESULTS

CORONET EAGLE STATISTICS

(BREMGARTEN A/B GERMANY, 2 OCTOBER TO 5 NOVEMBER 1980

- 1001 SORTIES FLOWN VS. 860 SCHEDULED
- 99.7% OF SORTIES SUCCESSFULLY COMPLETED
- 92.9% OF SORTIES CAPABLE OF RE-FLY WITHOUT MAINTENANCE
- 99.4% OF SORTIES CAPABLE OF RE-FLY WITHOUT RADAR MAINTENANCE
- AIRCRAFT MFHBF 1.97 HOURS
- RADAR MFHBF 23.1 HOURS

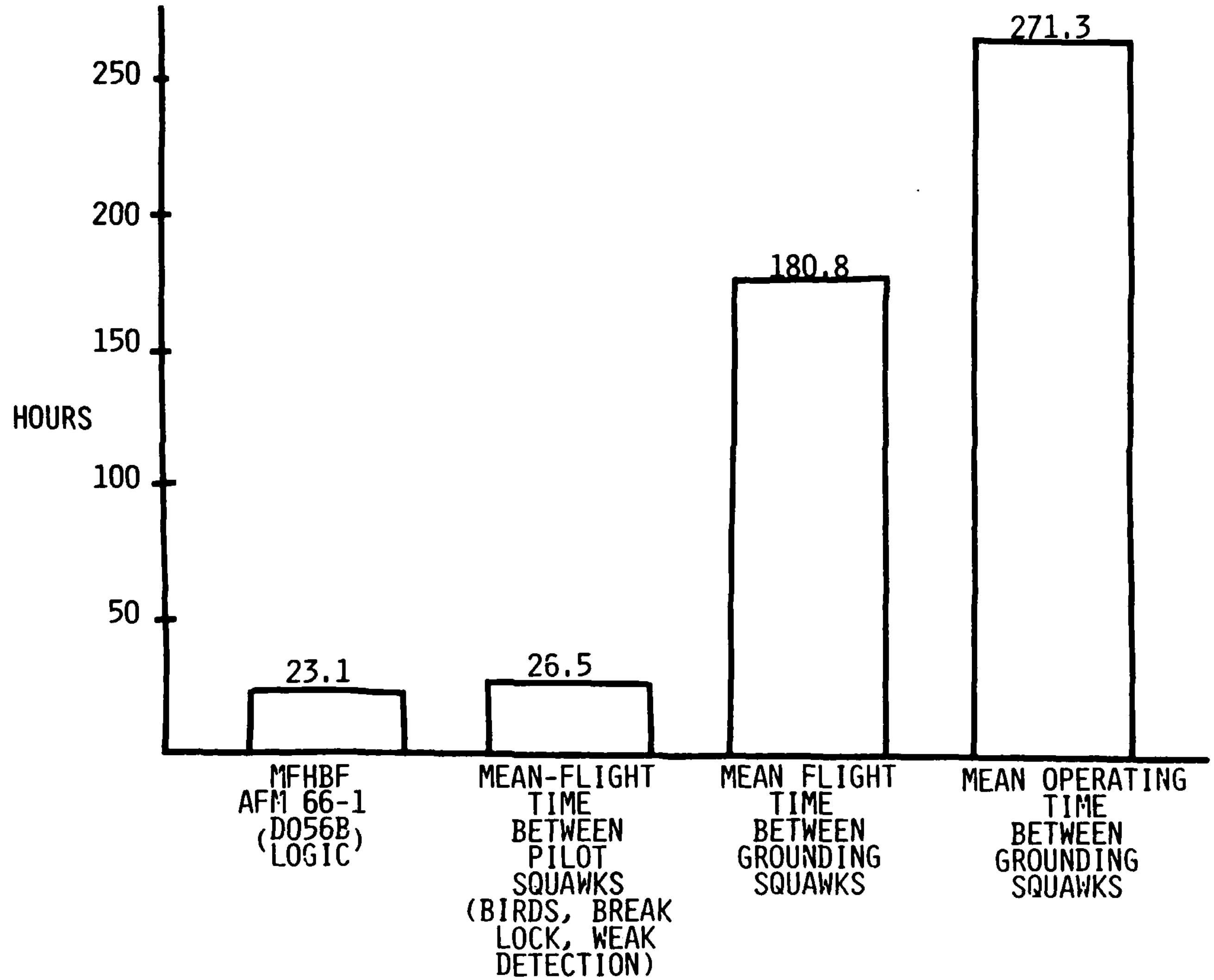
46A/1-53

RADAR RELIABILITY

The AFM 66-1 maintenance data, in conjunction with the flight hours accumulated during the Coronet Eagle exercise indicate a mean-flight-hours-between-failure (or MTBM-1 as it is currently described) of 23.1 hours with 47 "failures". There were only 41 pilot squawks with the additional 6 failures resulting from multiple LRU pulls, or multiple counting of associated maintenance reports covering the same event. Of the 41 pilot squawks, only 6 reported events requiring maintenance before re-fly (other pilot squawks were of a minor nature or had self-cleared before end of flight). Counting only the "hard" failures, and using the estimated radar operating time (1.5 X aircraft flight time) results in a calculated mean operating time between grounding squawks of 271.3 hours.

RADAR RELIABILITY

CORONET EAGLE



FAILURES	47	41	6	6

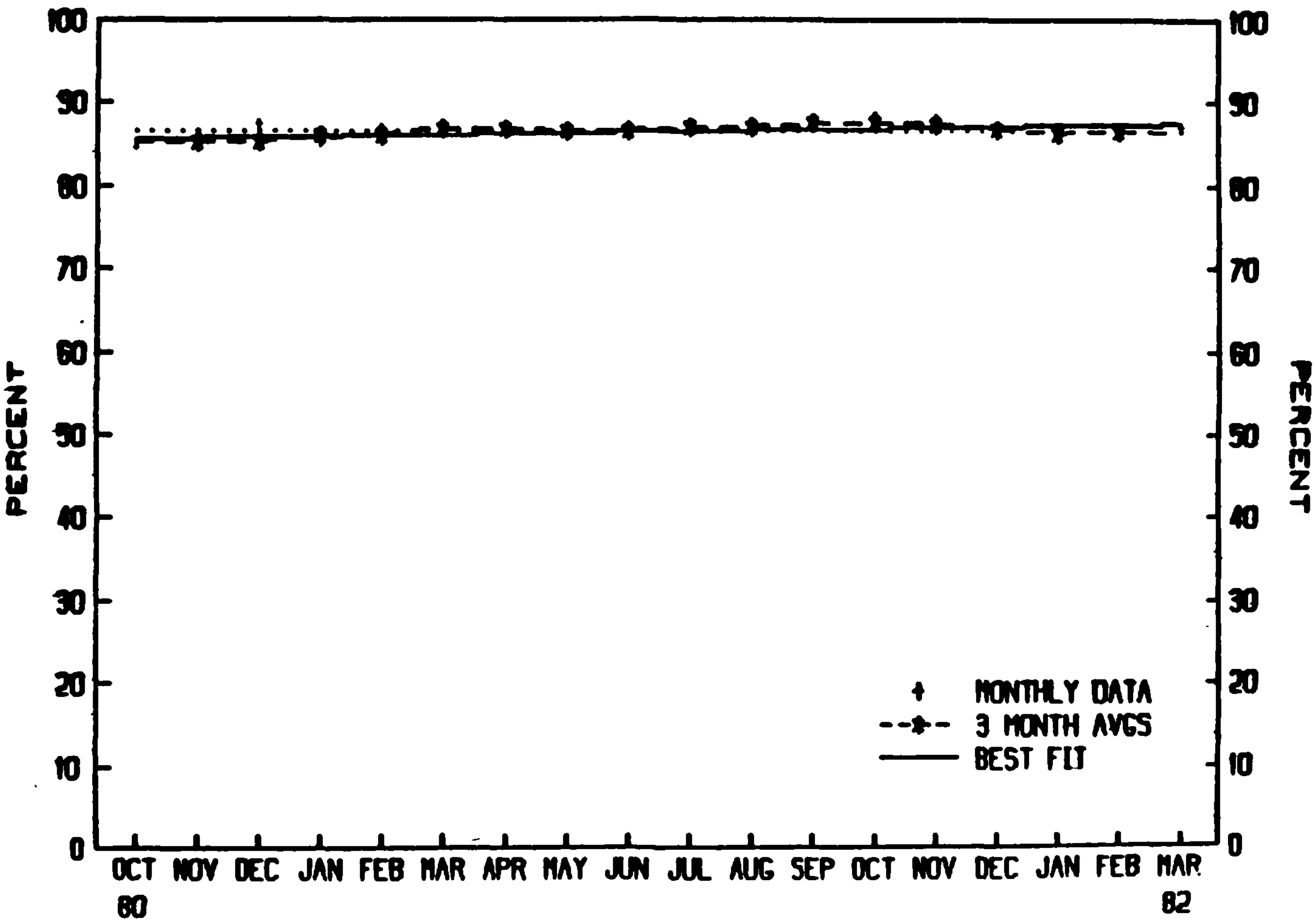
PERCENTAGE OF TIME WHEN RADAR WAS NOT SQUAWKED

OVER 85 PERCENT OF THE TIME THE PILOT DOES NOT SQUAWK RADAR PERFORMANCE. A SLIGHT IMPROVING TREND IS INDICATED BASED ON AIR FORCE-WIDE EXPERIENCE. FMC RATES ARE NOT AVAILABLE; HOWEVER, THIS CHART IS AN APPROXIMATION OF THE VALUES.

46A/6-6

F-15 APG-63 RADAR

PERCENTAGE OF TIME WHEN RADAR WAS NOT SQUAWKED



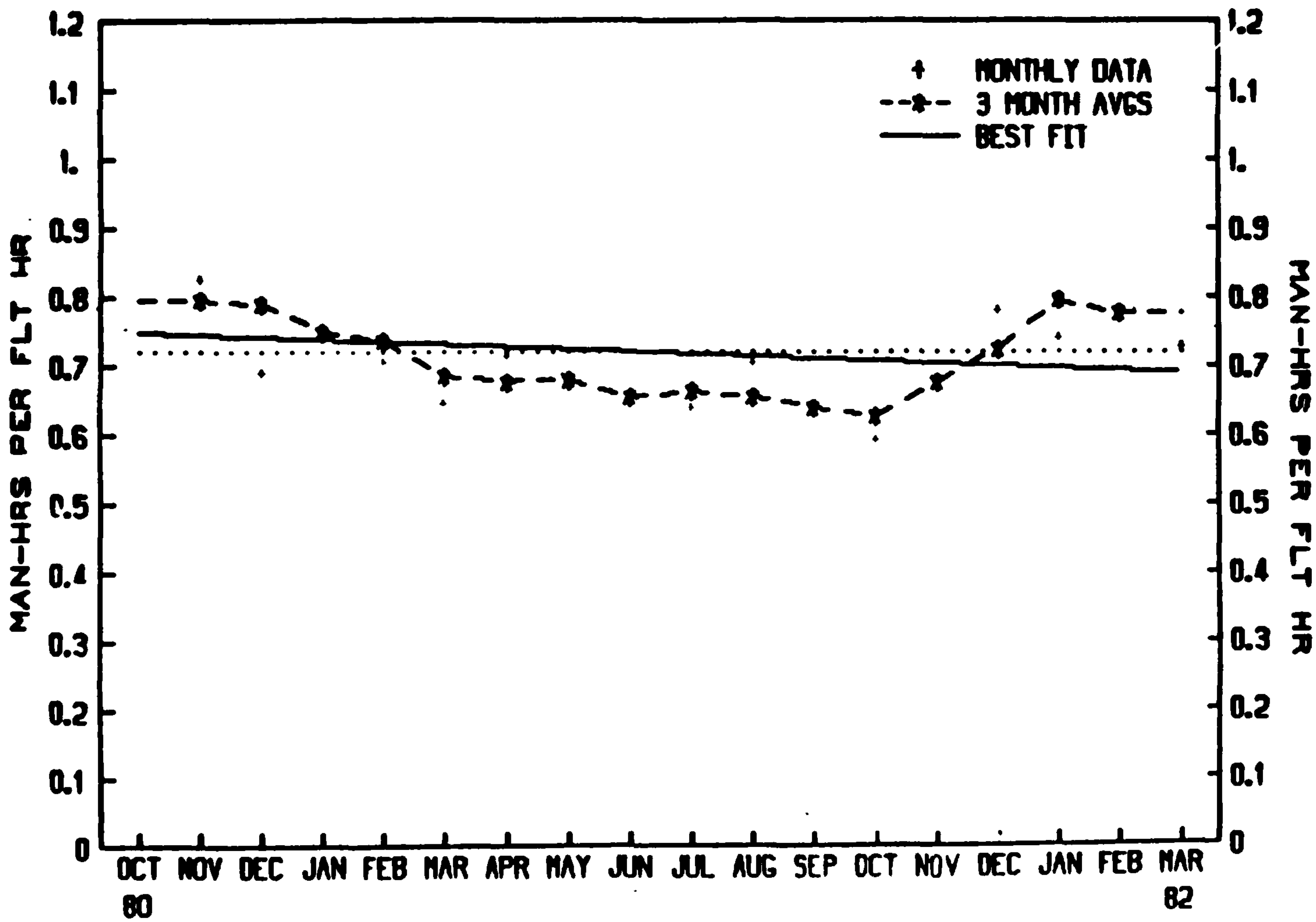
F-15 RADAR FLIGHTLINE

MAINTENANCE MANHOURS PER FLIGHT HOUR (MMH/FH)

The F-15 Radar has demonstrated a low flightline MMH/FH of 0.6 to 0.8 The Radar has been easy to maintain because of functional grouping, maintainability design features and BIT. AFM 66-1 data revealed the flightline MMH/FH for the F-15 Radar is only 15% higher than other radar sets that are less complex and have less operating functions and capabilities. MMH/FH for the F-15 Radar has decreased from October 1980 through March 1982.

F-15 APG-63 RADAR FLIGHTLINE

MAINTENANCE MANHOURS PER FLIGHT HOUR

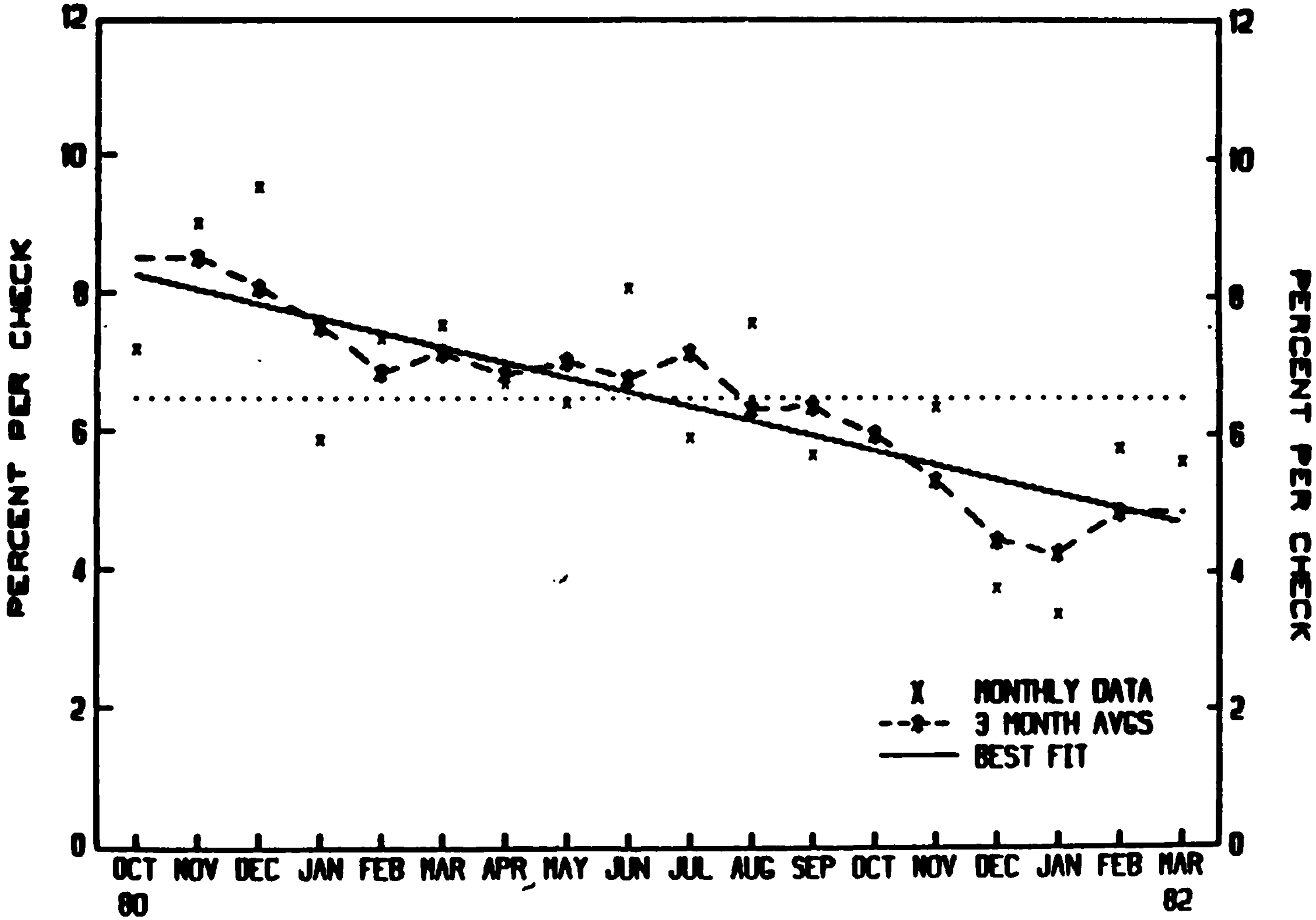


LRU NRTS RATE

LRU NRTS rate has decreased because of the following: availability of piece parts and spare SRUs at Intermediate and Depot Levels has improved. Software for the Intermediate Level AIS and Depot Level test stations has been improved to provide better fault isolation and testing procedures so that LRUs and SRUs are more easily repaired. The supply pipeline time for SRUs has decreased. Field training for maintenance personnel at Intermediate and Depot Levels has been improved. Technical manuals have also been improved.

F-15 APG-63 RADAR

LRU NRTS RATE



PROGRAM ELEMENTS

PROGRAM ELEMENTS

Many factors contributed to the results of the F-15 APG-63 radar program. The key development factors have been divided into five groups. This grouping assists in this case study analysis. However, these elements are not independent of each other and in fact have large overlaps.

PROGRAM ELEMENTS

- CONTRACT
- MANAGEMENT
- DESIGN
- MANUFACTURING
- TEST AND EVALUATION

41/8

CONTRACT

MILESTONES INFLUENCING RELIABILITY PROGRAMS

The character of reliability and maintainability programs has varied with each new weapon system procurement and has reflected the popular notions at the time the Request for Proposals (RFPs) were being prepared. The F-15 was likewise influenced by the reports and military standards in effect during the 1969 time period. These were:

- 1957--Advisory Group on Reliability Electronic Equipment (AGREE) report. Task 3 of the AGREE report set forth sequential testing with the concepts of Specified MTBF (θ_0), Minimum Acceptable MTBF (θ_1), Discrimination Ratio (θ_0/θ_1) and Decision Risks (α, β). Sequential testing grew in popularity and began to replace fixed-length testing as a requirement in many contracts.
- 1965--MIL-STD-781A-Reliability Tests: Exponential Distribution. This military standard captured the concepts of the AGREE report and expanded the application to include a "shopping list" of test plans and test levels. A method, which was later dropped in the "B" and subsequent revisions, for determining the number of production test articles based on MTBF, test time, and production rate was included. MIL-STD-781B, dated 15 November 1967, was in effect at the time of the F-15 contract award and two systems were selected for testing during RQT and PRT based largely on judgmental considerations and was applied to those equipments with MTBFs between 0 and 1,111 hours. Plan III and Level F were widely applied. Sine vibration of 2.2 gs peak acceleration at any non-resonant frequency between 20 and 60 cps was typical.
- 1968--AFR 80-5. This revision to Air Force Regulation 80-5 attempted to draw a distinction between two types of reliability. These were labeled as "hardware reliability" and "operational reliability." Up to this time there was considerable

emphasis on the "mission success" aspects of reliable performance and reliability was usually defined as a probability. During proposal negotiations, a probability of success requirement for a point intercept mission with a dedicated flight test program to demonstrate attainment was considered. This was dropped, subsequent to contract award, in favor of "hardware reliability" requirements at the air vehicle, subsystem, and component level including the radar.

- 1969--F-15 Contract Award. The reliability program was influenced to a large extent by the AGREE report, Military Standards and regulations in effect at the time of contract. Thirty-five MIL-STD-781B tests were required and the definitions of "hardware reliability" were widely applied (i.e., serial reliability calculations vs. mission essential). During pre-contract award negotiations, the F-15 Systems Project Office (SPO) made it very clear to all levels of prime contractor and subcontractor management including fiscal, engineering, and reliability/maintainability personnel, that high reliability and ease of maintenance was a firm contract requirement.

MILESTONES INFLUENCING RELIABILITY PROGRAM

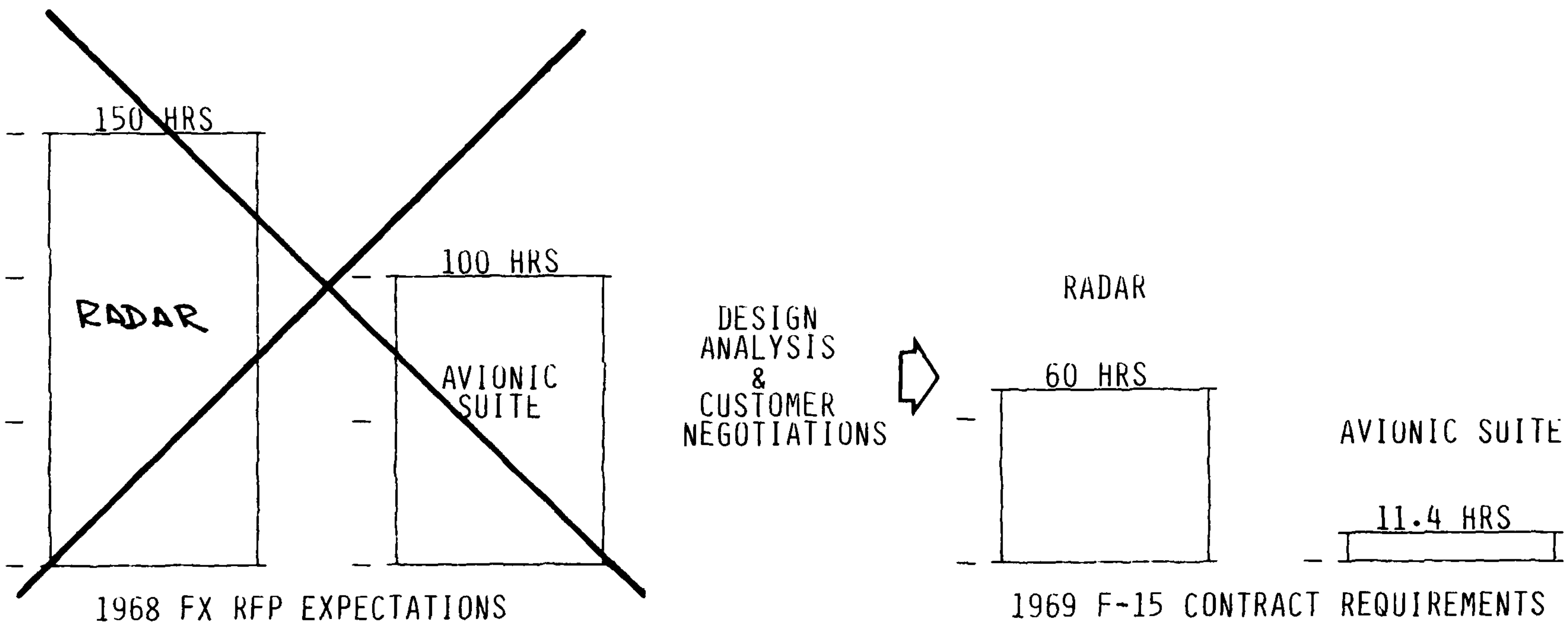
- 1957 AGREE REPT (SEQUENTIAL TESTING RECOMMENDED)
- 1967 MIL-STD-781B (RELIABILITY TESTS - EXPONENTIAL DISTRIBUTION)
- 1968 AFR 80-5 (HARDWARE RELIABILITY DEFINED)
- 1969 F-15 CONTRACT AWARDED

46A/1-9

DIFFICULT BUT ATTAINABLE REQUIREMENTS

- Contained in the original 1968 FX (later designated F-15) RFP was a requirement for a "minimum 150 hr MTBF radar." This was to be verified by an RADC/MIL-HDBK-217 prediction that indicated an MTBF at least 6 x 150 hrs or 900 hrs. The 150 hr MTBF was beyond usual expectations when compared to existing radars which were in the range of 5 to 15 hours MTBF and when viewed in terms of size, weight, power, and complexity that would be required to fulfill F-15 performance requirements. A prediction that was six times the 150 hours indicated how little faith was placed in the accuracy of reliability predictions at that time.
- An Avionic Subsystem requirement of 100 hours MTBF and an objective of 150 hours MTBF was also specified. This too was beyond reasonable expectations when compared to existing avionic subsystems. The radar was included as part of the avionic subsystem.
- Analyses conducted by MCAIR, HAC and Westinghouse Electric Company, indicating much lower numbers, were presented to the Air Force and after negotiations the radar and Avionic Subsystem (or Suite) MTBF values were lowered to difficult but attainable requirements.

DIFFICULT BUT ATTAINABLE REQUIREMENTS



46A/1-51

CONTRACT

The F-15 radar reliability requirements were established through an iterative process of analysis and negotiations prior to aircraft contract award. MCAIR used their F-4 radar experience as a baseline not only for reliability data, but other design parameters as well. Additional information was acquired from the radar engineering development program initiated by the Air Force in 1968, and analyses efforts by MCAIR and the competitors for the radar contract. Air Force engineers, familiar with various radar programs, also contributed significantly to the design requirements. Many alternatives were studied, and reliability levels were estimated for different hardware configurations, part quality levels, and cooling provisions.

The MIL standards then current for equipment design and test were invoked by the Air Force, but were tailored in several areas to match the aircraft. One of the most significant was that the standard vibration test requirement was replaced with requirements based on expected F-15 vibration levels. The MIL-STD-781B reliability test condition (Test Level F) was modified to use voltage limits as provided by the aircraft electrical system in lieu of the standard ±10% limits. Liquid and forced air cooling of the radar LRUs used simulated aircraft conditions rather than those specified by MIL-STD-781B.

The radar contract was awarded to Hughes after the competitive fly-off.

F-15 APG-63 RADAR RELIABILITY REQUIREMENTS

SPECIFICATIONS

	MTBF GROWTH REQUIREMENT	
• MIL-STD-781B	MTBF 30 HOURS ($\emptyset o$)	PREPRODUCTION
(TEST PLAN III)	45 HOURS	60TH PRODUCTION
(TEST LEVEL F)	60 HOURS	120TH PRODUCTION

- MICROCIRCUIT SCREENING REQUIRED
- ELECTROMECHANICAL RELAY LIMITS ON USAGE
- THERMAL REQUIREMENTS INCLUDED NOMINAL AND MINIMUM DESIGN LIQUID/COOLING AIR FLOW SPECIFICATION AND PRESSURE DROP CHARACTERISTICS

MCAIR REQUIREMENT

- MIL-STD-785 RELIABILITY PROGRAM
- STANDARDIZATION AND PARTS CONTROL PROGRAM INCLUDING A PARTS CONTROL BOARD

46A/1-15

RADAR - MAJOR IMPACT ON RELIABILITY GUARANTEES

- Of the 111 reliability guarantees, the radar's importance was magnified by its driving impact on at least three of the numbers. In a sense, the radar represented triple jeopardy to MCAIR.

RADAR - MAJOR IMPACT ON RELIABILITY GUARANTEES

GUARANTEE & DEMO METHOD		IMPACTED BY RADAR
1	AIR VEHICLE (CATEGORY II)	X
22	SUBSYSTEMS (CATEGORY I/II)	X
35	EQUIPMENT (MIL-STD-781B)	X
36	EQUIPMENT (CATEGORY I/II)	-
17	EQUIPMENT (QUAL TESTS)	-
111	TOTAL	3

WHAT COULD HAVE HAPPENED

A RADAR MTBF OF ONLY 15 HOURS WOULD HAVE RESULTED IN FAILURE TO MEET THE AIR VEHICLE MTBF OF 3.5 HRS, THE AVIONIC SUITE MTBF OF 11 HOURS, AND THE MIL-STD-781B TESTS (30/45/60 HOURS)

46/1-14

F-15 SUBSYSTEM RELIABILITY REQUIREMENTS

The following example demonstrates the numerical importance of the radar on subsystem reliability requirements.

Air Vehicle		Avionics (inc. Radar)		Airframe		Armament		Propulsion,		etc.
$\frac{1}{3.5}$	=	$\frac{1}{11.4}$	+	$\frac{1}{14}$	+	$\frac{1}{23}$	+	$\frac{1}{47}$	+.......	$\frac{1}{16}$

$$= -\frac{1}{30} \quad \text{Delete 30 hr Radar}$$

$$+\frac{1}{15} \quad \text{Add 15 hr Radar}$$

$$\frac{1}{3.1} = \frac{1}{8.3} + \frac{1}{14} + \frac{1}{23} + \frac{1}{47} \qquad \frac{1}{16}$$

Air Vehicle & Avionics below required values

F-15 SUBSYSTEM RELIABILITY REQUIREMENTS

SUBSYSTEM	MTBF
AIR VEHICLE	3.5
AVIONICS (INC 30 HR MTBF RADAR)	11.4
AIRFRAME	14
ARMAMENT/WEAPON DELIVERY	23
PROPULSION	47
ELECTRICAL	75
CREW STATION	89
FLIGHT CONTROLS	91
HYDRAULIC	110
FUEL	155
ENVIRONMENTAL CONTROL	158
SECONDARY POWER	403

VERIFIED DURING CATEGORY II FLIGHT TEST PROGRAM

46A/1-50

RADAR AND AIR VEHICLE REQUIREMENTS ATTAINED EARLY IN PROGRAM

Growth Curve and Category I/II Tests

- The "Planned Growth" s-shaped curve was constructed based on three sets of estimated values that represented the air vehicle MTBFs for first flight, end of Category II testing, and end of 1977. The corresponding estimated radar MTBFs were 15 hrs, 30 hrs and 60 hrs. The requirement for a 3.5 hr air vehicle MTBF, included the radar and all other equipment as a sub-set of the total.
- An MTBF calculated from limited first flight data was deemed to lack significance so that no requirements were placed on this event. Category I flight test results of 20 hrs MTBF for the radar is the only available approximation of early flight experience derived from MCAIR-calculated and Air Force-approved results.
- During Category II flight tests, the Air Force Systems Effectiveness Data System (SEDS) at Edwards Air Force Base was used to aid in collecting and evaluating test results. The Air Force conducted the flight test program and evaluated the results with inputs and support from MCAIR and suppliers. With information obtained from aircraft equipment installed elapsed time indicators, accurate records were obtained on the actual operating time of engines, radars and other equipment. Based on this, a 46 hr MTBF radar and a 3.8 hr MTBF for the air vehicle was calculated.
- The 60 hr MTBF estimate for the end of 1977 was never directly measured using operating time and Air Force/MCAIR agreed-to relevant failure determinations.

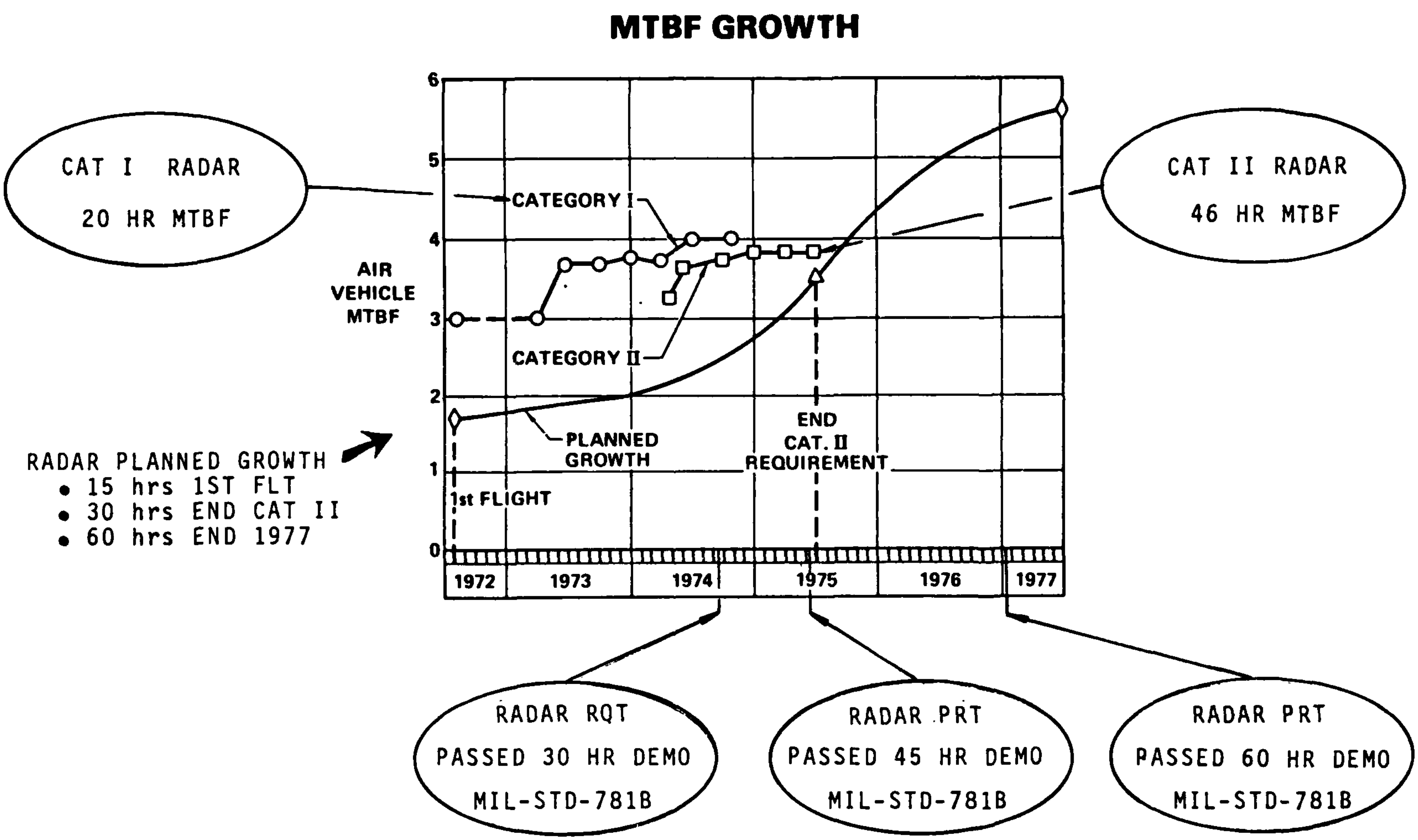
MIL-STD-781B Tests

- Reliability Qualification Test (RQT) passed in September 1974 with a θ_o = 30 hrs.
- Production Reliability Test (PRT) passed in June 1975 with a θ_o = 45 hrs.
- Production Reliability Test (PRT) passed in January 1977.
- Fifth PRT passed in 1982.

46B/1-18

<u>Summary</u>: By June of 1975, the F-15 had accumulated 2220 hrs of Category I/II flight tests and several thousand hours of radar test time. Air vehicle MTBFs in excess of the 3.5 hrs required and radar MTBFs equal to or exceeding the 30/45/60 hr requirements were attained.

RADAR & AIR VEHICLE REQUIREMENTS ATTAINED EARLY IN PROGRAM



FAILURE DEFINITIONS

- ALL FAILURES RELEVANT UNLESS SHOWN OTHERWISE
- INSTALLATION DAMAGE, MISHANDLING, TEST EQUIPMENT FAILURES NON-RELEVANT
- PATTERN FAILURES REQUIRE CORRECTIVE ACTION
- SECONDARY FAILURES NON-RELEVANT
- FAILURES WHICH WERE ELIMINATED BY SOFTWARE CHANGE ARE NON-RELEVANT

46A/1-20

GRIDDED TRAVELING WAVE TUBE (GTWT)

- 2000 HR MTBF REQUIRED
- MIL-STD-781B TEST PLAN V
- TEST PROCEDURE SUBJECT TO MCAIR APPROVAL
- 2500+ HOURS OF TESTING WITH NO FAILURES

46A/1-21

F-15 RADAR M REQUIREMENTS

The Radar quantitative M specified parameters were established by analytical methods and then assigned as Radar requirements which had to be demonstrated. This approach was taken to achieve a design that would be supportable by the customer within the three level maintenance concept with low maintenance actions and low maintenance manhours while at the same time with the capability of providing high levels of Radar availability. These requirements had a definite direct impact on the Radar design and have influenced the use of such features as Built-In-Test, quick disconnect connectors, modular construction, automatic testing, and rapid LRU replacement without adjustments or boresighting. By directive, persuance of these requirements was to be in consonance with the Integrated Logistic Support function and the optimum repair level analysis to achieve the Radar M requirements at the lowest logistic support cost. The specified MTTR of 1.55 hours at Organization and Intermediate Levels was suballocated. This suballocation was made to assign the time for Avionic Intermediate Station (AIS) testing of the Radar to MCAIR while allocating all other testing and maintenance at both Organizational and Intermediate Levels to the Supplier.

F-15 APG-63 RADAR MAINTAINABILITY REQUIREMENTS

MAINTAINABILITY SPECIFICATION

- MTTR* - 1.55 HOURS (ORGANIZATIONAL AND INTERMEDIATE)
  - MTTR - 0.78 HOURS (MCAIR ALLOCATIONS)
  - MTTR - 0.77 HOURS (HUGHES REQUIREMENT)
- MTBMA** - 15 OPERATE HOURS

---

*MEAN MANHOURS TO REPAIR

**MEAN TIME BETWEEN MAINTENANCE ACTIONS

F-15 APG-63 BUILT-IN-TEST REQUIREMENTS

- GENERAL REQUIREMENTS PS 68-870011 PROCUREMENT SPECIFICATION
  - REMOVE AND REPLACE LRUs WITHOUT A NEED FOR AIRCRAFT ADJUSTMENT EXCEPT FOR BIT CAPABILITY SUCH AS SYSTEM CALIBRATIONS
  - MINIMIZE A NEED FOR FLIGHT-LINE AGE
- SPECIFIC REQUIREMENTS
  - DETECT AND ISOLATE TO LRU FOR 95% OF MALFUNCTIONS FALSE ALARM (FA) <2%
  - LESS THAN 2 MINUTES TO PERFORM A FULL BIT SEQUENCE
  - FAULTS DETECTED ARE ASSIGNED TO A SINGLE LRU
  - FAULT INDICATORS SHALL BE PROVIDED ON EACH LRU EXCEPT FOR THE ANTENNA AND CONTROL PANEL WHICH ARE LOCATED ON THE RDP

F-15 FSD FIRM FIXED PRICE CONTRACT WITH COST SHARING

PROGRAM COST	FSD
• ABOVE CEILING	ALL COSTS ASSUMED BY CONTRACTOR
CEILING (127.3%)	
• ABOVE TARGET	COSTS SHARED 90%/10%
TARGET (100%)	
• BELOW TARGET	UNDERRUN 100% CONTRACTOR

46A/2

MANAGEMENT

46/1-48

MANAGEMENT PLANNING AND CONTROL

Technical, cost and schedule requirements and controls were established between Air Force and MCAIR and in turn passed on to suppliers through contract documentation. Technical requirements, including demonstration plans, were described in the prime item and procurement specifications, and tasks, schedules and management approaches were described in the reliability program plans. Control was exercised through formal reviews, data approval, and considerable personal contact between management and engineering personnel.

MANAGEMENT PLANNING AND CONTROL

- AIR FORCE/MCAIR
  - ✓ F-15 AIRPLANE CONTRACT
  - ✓ PRIME ITEM SPECIFICATION
  - ✓ RELIABILITY PROGRAM PLAN
- MCAIR/HAC
  - ✓ PURCHASE ORDER
  - ✓ PROCUREMENT SPECIFICATION
  - ✓ RELIABILITY PROGRAM PLAN

⇩

REQUIREMENTS ESTABLISHED, ORGANIZATIONS IDENTIFIED, SCHEDULES PREPARED

46A/1-67

MCAIR TO HAC RELIABILITY REQUIREMENTS

PROCUREMENT SPECIFICATION

- 30/45/60 HR MTBF REQUIRED PER MIL-STD-781B
- MICROCIRCUITS PER MIL-STD-883
- JAN TX SEMICONDUCTORS PER MIL-S-19500
- MILITARY EXTRA RELIABILITY (ER) PARTS
- MIN RADAR BURN-IN TO BE SPECIFIED
- DETAILED MILESTONE PLAN

GENERAL MANAGEMENT REQTS

- RELIABILITY PROGRAM PER MIL-STD-785
- PREFERRED PARTS PROGRAM PARTS CONTROL BOARD
- FORMAL RELIABILITY TESTS

DATA REQUIREMENTS

- DETAIL PART SPECIFICATION
- PARTS LIST
- NON STANDARD PARTS REQUESTS
- RELIABILITY PROGRAM PLAN
- RELIABILITY PREDICTIONS
- FAILURE MODE ANALYSIS
- FAILURE REPORTS
- FAILURE ANALYSIS
- RELIABILITY STATUS REPORT
- RELIABILITY TEST PROCEDURE
- RELIABILITY TEST REPORT

46/1-13

MAINTAINABILITY

A vigorous M program plan was implemented for the radar set and was accomplished in accordance with MIL-STD-470. A M analysis was prepared, M design criteria was established and trade studies were performed. During the life of the M program, M engineers actively participated in design reviews and technical coordination meetings.

M qualitative specification requirements were established for the radar set. These M quantitative requirements were used in the Procurement Specification and Prime Item Specification.

Maintainability verification plan and test was one of the major outputs of the M program. Verification of the M requirements was accomplished by test and performed in accordance with MDC Report G117. This test confirmed that the Radar Set met its M quantitative requirements.

The Maintainability Program Status Report, Contractor Data Requirements List (CDRL), Sequence No. A145, was submitted on a regular basis to the Air Force and reported the progress of the M program for the radar set.

Maintenance Concept was established for the radar set early in the program. The concept involves maximum use of BIT and the radar BIT matrix for fault isolation. The concept took advantage of M design criteria and design features that were incorporated into the design of the radar and the aircraft installation. The concept utilized computer operated automatic test stations at Intermediate and Depot Levels. Optimum Repair Level Analysis (ORLA) was used to determine the best level of repair for all LRUs and SRUs.

Maintenance

- Maintainability Program Plan
- Maintainability Specification Requirements
- Maintainability Program Status Report
- Maintenance Concept

MCAIR TO HAC
MAINTAINABILITY REQUIREMENTS

PROCUREMENT SPECIFICATION

- MTBMA NOT LESS THAN 15 HOURS
- MMTR SHALL NOT EXCEED 1.55 HOURS
- BUILT IN TEST:
  FAULT DETECTION - 95%
  FAULT ISOLATION - 95%
- ORGANIZATION AND INTERMEDIATE LEVEL TASK DEFINITIONS
- VERIFICATION TESTS
- DESIGN COMPATIBLE WITH THREE LEVEL MAINTENANCE CONCEPT

GENERAL MANAGEMENT REQTS

- MAINTAINABILITY PROGRAM PER MIL-STD-470
- TEST COMPATIBILITY/DESIGN REQUIREMENTS PER MCAIR REPORT G667
- MAINTAINABILITY REQUIREMENTS VERIFICATION STANDARDS PER MCAIR REPORT G117

DATA REQUIREMENTS

- DESCRIPTION AND MAINTENANCE CONCEPT
- MAINTAINABILITY DATA
- MAINTENANCE ANALYSIS
- MAINTAINABILITY VERIFICATION PLAN
- MAINTAINABILITY VERIFICATION REPORT
- ORLA DATA

46A/1-57

MCAIR R&M ASSURED THROUGH ORGANIZATION AND COMPANY PROCEDURES

- R&M ENGINEERS REPORT TO PROJECT ENGINEER AT SAME LEVEL AS DESIGN GROUPS
- R&M ISSUES NOT RESOLVED BY PROJECT MAY BE ELEVATED TO TOP MANAGEMENT BY FUNCTIONAL SUPERVISORS
- R&M APPROVAL (SIGNATURE) REQUIRED FOR RELEASE OF PROCUREMENT SPECIFICATIONS, INSTALLATION AND ASSEMBLY DRAWINGS, DEVELOPMENT TEST PROCEDURES AND REPORTS, AND SUPPLIER DATA REQUIREMENTS

MCAIR ORGANIZATION

Throughout the history of the F-15, Reliability (R) and Maintainability (M) activities have been primarily project functions reporting to an engineering chief who in turn reported to the director of engineering. Early in the program (1969 period), the R&M effort was led by a chief (R.A. Eberhard) whose background was largely operations and systems analysis which proved to be valuable since the activity involved numerous trade studies, predictions, plans, and their impact on life-cycle costs. During the 1973 time period, R&M became part of a larger group including avionics and crew station design. This organizational change proved to be effective in that the chief (H.W. Hamm) had a predominant avionics background and was very helpful in integrating radar design and testing efforts including MIL-STD-781B activities. In the 1976 and later periods, the chief had a background in laboratory and flight testing (J.R. Hanson was the chief for the longest period). This also proved effective in integrating all testing activities including production reliability tests (PRT) with the resultant product improvements in radar R&M.

HAC APG-63 ORGANIZATION

F-15 RADAR
PROGRAM OFFICE

↓

F-15 RADAR
RELIABILITY

↓

CONDUCT PROGRAM DEFINITION,
COORDINATION, AND CONTROL

TO

ALL ASSISTING DIVISIONS

VIA

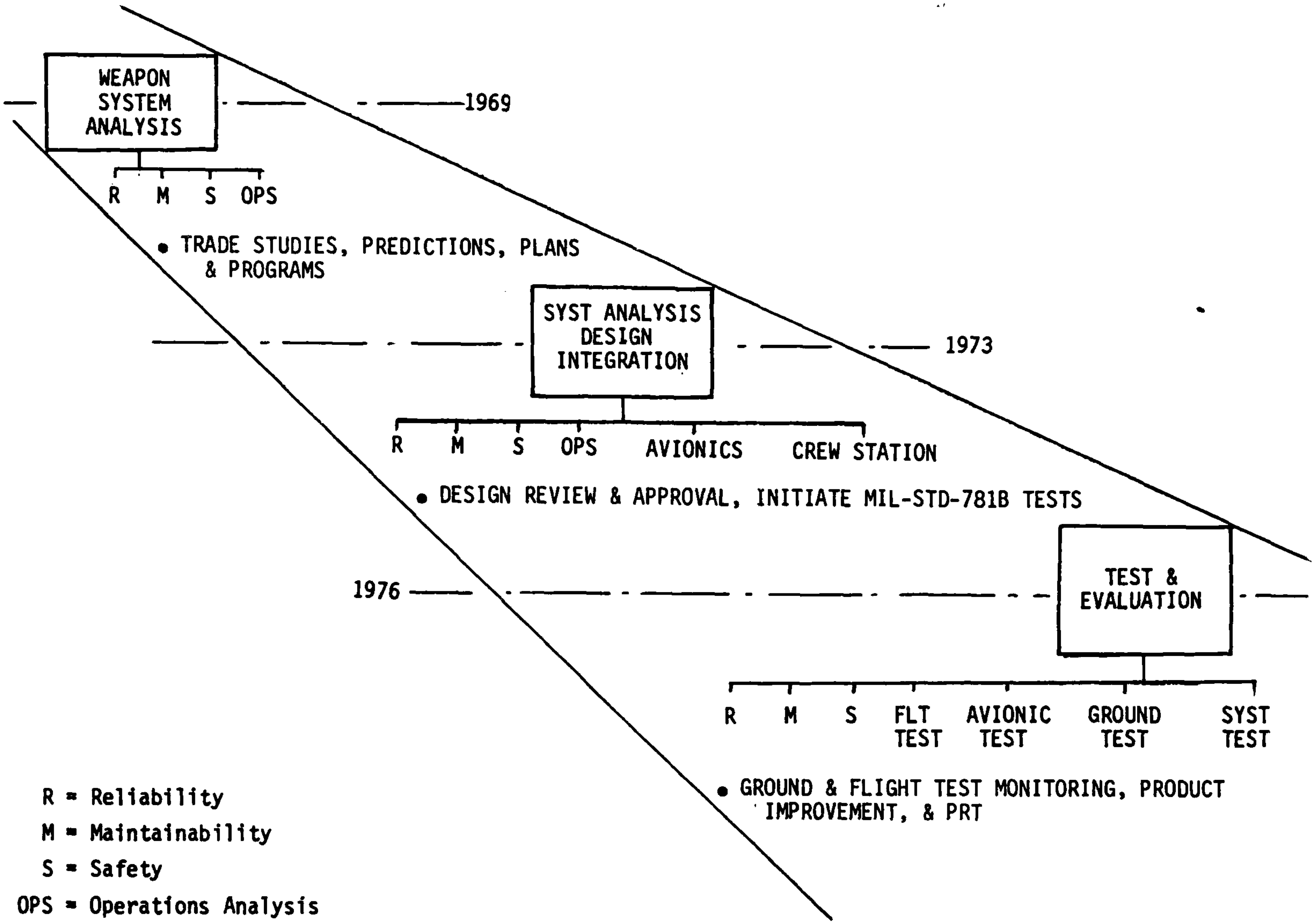
PRODUCT EFFECTIVENESS REQUIREMENTS SUMMARY (PERS)
WORK AUTHORIZATION DELEGATION (WAD)
MINOR ASSIST WORK (MAW)

FOR

SYSTEMS RELIABILITY ENGINEERING
PRODUCT RELIABILITY ENGINEERING
PARTS MATERIALS AND PROCESSES
RELIABILITY TESTING
FAILURE ANALYSIS AND REPORTING
DATA PROCESSING

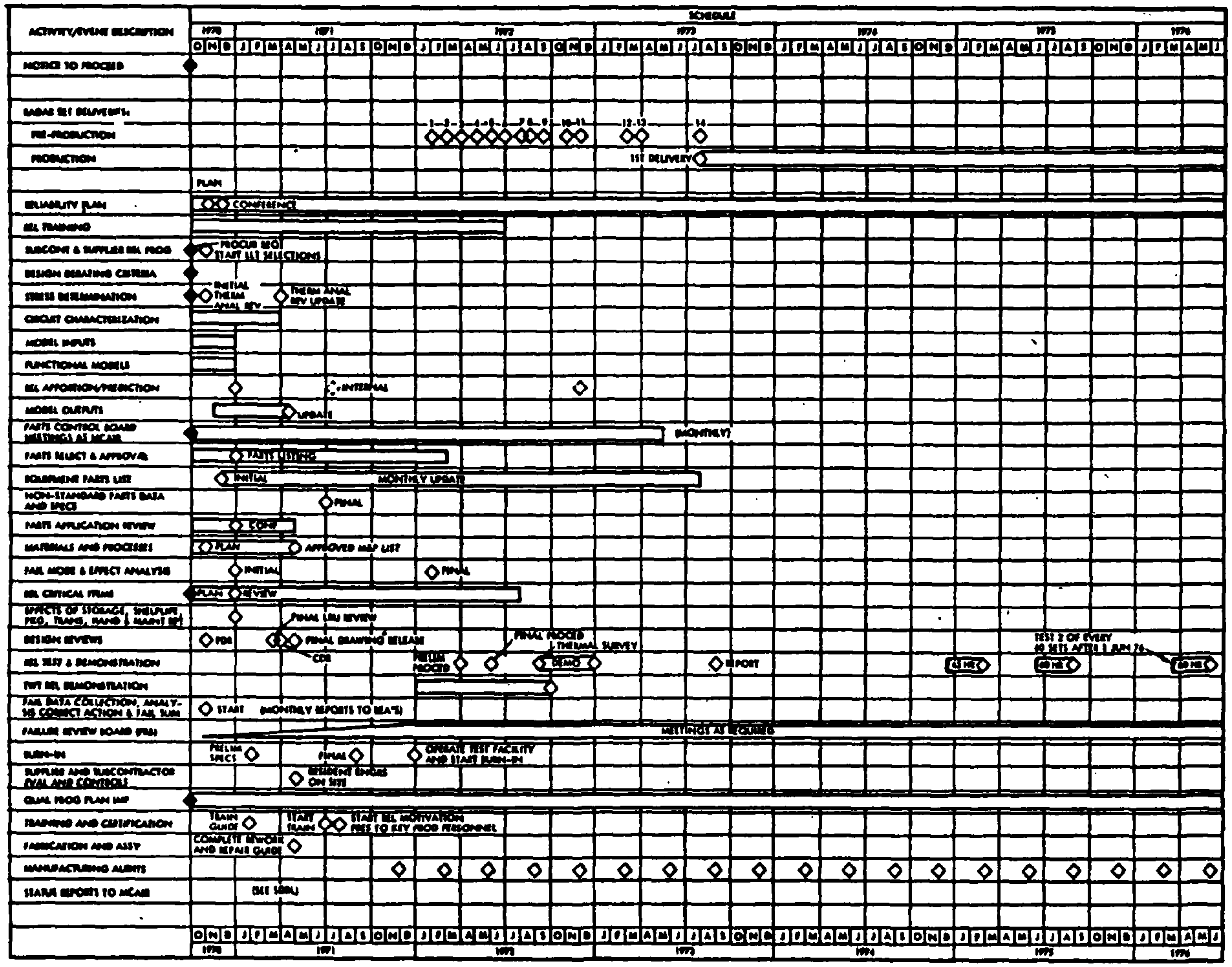
46A/1-68

MCAIR ORGANIZATION CHANGED AS PROGRAM PHASE CHANGED



R = Reliability
M = Maintainability
S = Safety
OPS = Operations Analysis

F-15 APG-63 RELIABILITY SCHEDULE



MCAIR F-15 APG-63 RADAR R&M

PROGRAM FEEDBACK

CLOSED LOOP EVALUATION AND REPORTING

INTEGRATED CORRECTIVE ACTION PROGRAM

- ICAP TEAMS FORMED TO REVIEW FAILURE DATA
  - FAILURES IN MCAIR AND HAC MANUFACTURING
- ESTABLISHED TRACKING SYSTEM ON CORRECTIVE ACTIONS AND THEIR EFFECTIVENESS

EAGLE WATCH PROGRAM

- EAGLE WATCH TEAMS ACTIVATED INITIALLY AT AF BASES
  - REPORTED FLIGHT SQUAWKS/LRU REMOVALS/BASE PROBLEMS
- MCAIR PACER-WEB PROGRAM ACTED AS INITIAL DEPOT
  - POSITIVE DATA AVAILABLE ON REPAIR ACTIONS

46/1-25

MCAIR MANAGEMENT

- TECHNICAL COORDINATION MEETINGS
  - SPO/AFLC/MCAIR/HUGHES
  - MONTHLY FORMAL MEETINGS
  - PROBLEM SOLVING
    - -- ACTION ITEMS
    - -- FOLLOW UP

DESIGN

46A/1-24

DESIGN

- TRADE STUDIES
- DESIGN FEATURES
- THERMAL ANALYSIS
- VIBRATION
- PARTS AND MATERIAL CONTROL
- DERATING
- PREDICTIONS AND ANALYSES
- FAULT ISOLATION/BIT
- SOFTWARE

46A/3-4

TRADE STUDIES

46A/6-10

F-15 APG-63 PRODUCT APPROACH

- EMPHASIS PLACED ON DESIGN ANALYSIS AND TRADE-OFFS
  - COMPONENTS -- TO SELECT ONLY HIGH RELIABILITY PARTS
    -- TO REDUCE NUMBER OF PART TYPES
    -- METHOD OF COMPONENT MOUNTING
  - THERMAL DESIGN -- TO SIGNIFICANTLY REDUCE COMPONENT JUNCTION TEMPERATURE TO COOLING AIR TEMPERATURE OVER THAT OF CONVENTIONAL DIPs
  - STRUCTURAL DYNAMICS -- TO SIGNIFICANTLY REDUCE TRANSMISSIBILITY (Q) AND THUS VIBRATION IMPOSED ON COMPONENTS
  - MAINTAINABILITY -- ELIMINATE ADJUSTMENTS AND PERIODIC MAINTENANCE, IMPROVED TESTING, USE PLUG-IN MODULES AND PROVIDE EASIER COMPONENT REPLACEMENT
  - HIGH DENSITY PACKAGING -- TO IMPROVE RELIABILITY AND REDUCE COST AND WEIGHT THROUGH REDUCED CONNECTORS, INTER-CONNECTIONS, MODULES, LRUs, ETC.

46A/6-11

TRADE STUDIES

Many trade studies were performed while the aircraft and radar configurations were being defined, and reliability and maintainability were important factors in the discussions. BIT mechanization was one of the earlier trade studies, and the chart on the facing page illustrates how numerical scores were assigned in this instance. The actual design for the F-15 utilized a combinination of two outlined approaches (avionics status panel in the wheel well with fault indicators on each LRU).

BIT MECHANIZATION TRADE STUDY

MECHANIZATION / CONSIDERATION	1. SHARED USE OF TACTICAL COCKPIT DISPLAY		2. CENTRALIZED DISPLAY OF LATCHING FAULT INDICATORS (WHEEL WELL)		3. LATCHING FAULT INDICATOR ON EACH LRU		4. COMPUTER-CONTROLLED ALPHANUMERIC BIT PAPER TAPE PRINTER (WHEEL WELL)		5. RF DATA LINK TO TRANSMIT FAULT DATA TO GROUND STATION	
	COMMENTS	SCORE	COMMENTS	SCORE	COMMENTS	SCORE	COMMENTS	SCORE	COMMENTS	SCORE
1. PERMANENCE OF READOUT Maximum Score: 10	BAD - Readout lost when power not applied or when CCC is removed	2	GOOD - Readout held until manually reset. Can become separated from faulty LRU	8	EXCELLENT - Readout held until manually reset after replacement of faulty LRU	10	GOOD - Tape can become separated from aircraft or faulty LRU	8	FAIR - Record is likely to become separated from faulty LRU	6
2. COST, WEIGHT, AND SIZE Maximum Score: 10	EXCELLENT - Display already provided for other functions	10	GOOD - 7 lb + wiring, $2 K unit cost, 390 cu. in.	8	EXCELLENT - Incremental cost & weight, $10 and 0.006 lb. per LRU	10	FAIR - Requires increased CCC storage, $4.7 K, and 10 lb.	6	POOR - Requires signal conditioning, computer storage, logic interface with data terminal & new data link messages	4
3. RELIABILITY Maximum Score: 5	EXCELLENT - No degradation, existing display	5	GOOD - Two connectors between LRU and Indicator	4	EXCELLENT - High reliability indicator is contained in LRU	5	FAIR - Tape unit is electro-mechanical device	3	POOR - Complex mechanization	2
4. MAINTAINABILITY Maximum Score: 5	EXCELLENT - No increase in maintenance actions	5	GOOD - Indicators showing failed LRU's must be manually reset after LRU replacement	4	EXCELLENT - LRU indicator reset as part of LRU repair	5	POOR - Tape reader must be loaded before and unloaded after each flight	2	FAIR - Additional functions to be maintained	3
5. COMPUTER STORAGE REQUIREMENTS Maximum Score: 20	EXCELLENT - Display storage already provided for other functions	20	EXCELLENT - No storage required	20	EXCELLENT - No storage required	20	FAIR - Approximately 500-32 bit computer words required	12	BAD - BIT data must be formated and stored until transmission	5
6. MAINTENANCE ACCESS Maximum Score: 10	FAIR - Technician must provide external or APU power and view readout in cockpit	6	EXCELLENT - Display always visible from ground level without opening doors	10	BAD - Technician must open doors to view Indicators	2	EXCELLENT - Tape printer always accessible	10	POOR - Technician must retrieve data from data link recorder prior to maintenance on aircraft	4
TOTAL SCORE: 60	SHARED TACTICAL DISPLAY	48	CENTRALIZED FAULT INDICATORS	54	FAULT INDICATOR ON EACH LRU	54	BIT TAPE PRINTER	41	RF DATA LINK	24

GP74 1030 24

ANALYSIS OF DESIGN APPROACH VIA MATH MODEL

(DESIGN CHANGES ARE EVALUATED RAPIDLY VIA COMPUTER)

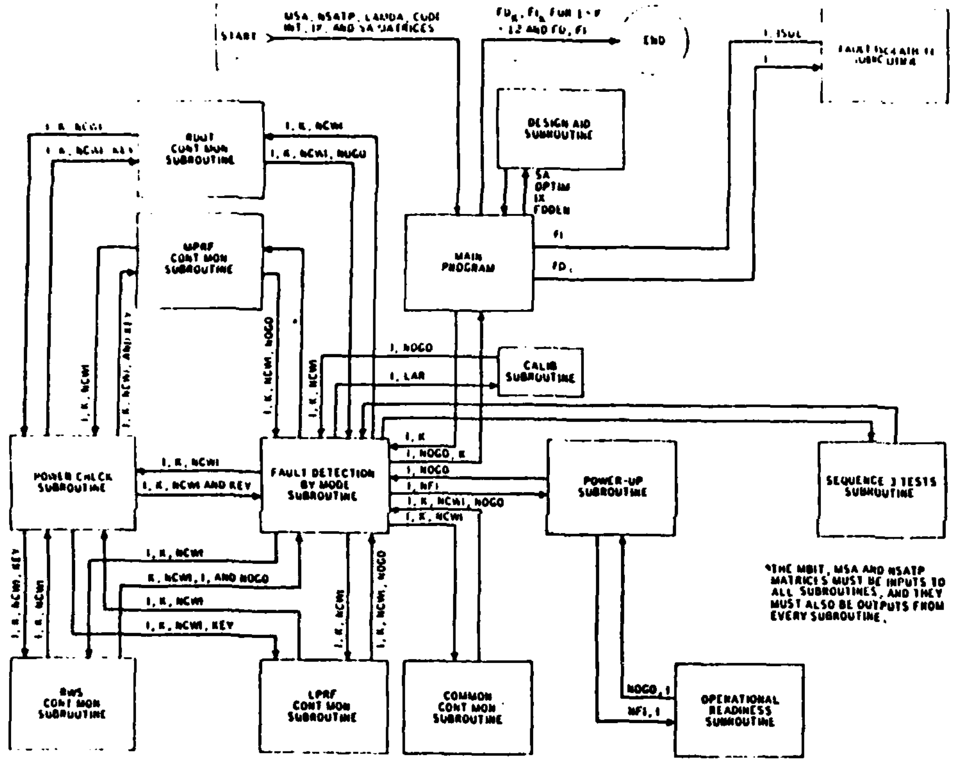


Figure 9.2.4.1. Main Program/Subroutine Calling Schematic Diagram

F-15 BUILT IN TEST SIMULATION RESULTS

MODE NUMBER	MODE NAME	FAULT DETECTION PROBABILITY
1	VELOCITY SEARCH TRACK	0.95583
2	VELOCITY SEARCH	0.97584
3	SHORT RANGE SEARCH TRACK	0.97337
4	SHORT RANGE SEARCH	0.96940
5	LONG RANGE SEARCH TRACK	0.97225
6	LONG RANGE SEARCH	0.96471
7	DOPPLER	0.96891
8	PULSE TRACK	0.95584
9	PULSE SEARCH	0.96483
10	MAP	0.95613
11	AIR/GROUND RANGING	0.14945
12	BEACON	0.96511

FAULT ISOLATION PROBABILITY

0.95149

Figure 9.1. BIT Test Thoroughness Results

Changes

During the program, numerous hardware changes were introduced for cost savings and for performance improvements. The following twelve charts depict some of these changes that also significantly affected Reliability and Maintainability. By utilizing new technology, the F-15 APG-63 Radar was able to improve both performance capability and Reliability.

46B/1-21

COMBINE ANALOG I/O MODULES (081 LRU)

VECP 235; EFFECTIVE RADAR SET 40

- REPLACEMENT OF TWO MODULES USING DISCRETE PARTS (ADA ELECTRONICS, ANALOG OUTPUT) BY ONE NEW MODULE USING INTEGRATED CIRCUITS
  - SPACE AND WEIGHT SAVINGS (1 MODULE ONLY: 0.5 LB)
  - INCREASED RELIABILITY:
    - FEWER INTERCONNECTIONS
    - FEWER PARTS
    - FEWER MODULES
  - LOWER LRU COST (OPTIONS 2-5 APPROXIMATELY $327K; ADDITIONAL COLLATERAL SAVINGS $250K)
  - LRU INTERCHANGEABLE WITH PRIOR CONFIGURATION

46A/6-12

LIMITING AMPLIFIER HYBRID COMMON DESIGN

(VECP 315; EFFECTIVE RADAR SET 057)

- A SINGLE LIMITING AMPLIFIER HYBRID IS USED FOR HPRF SEARCH AND HPRF TRACK (7A4 & 7A5 MODULES)

RESULT: SIMPLIFICATION THROUGH COMMON DESIGN

- FOUR IDENTICAL HYBRIDS REPLACE SIX HYBRIDS OF THREE DIFFERENT TYPES - IMPROVED PRODUCIBILITY
- PERFORMANCE IMPROVEMENT:
  - GREATER BANDWIDTH WITH SIMPLE TUNING
  - IMPROVED DETECTION IN HIGH CLUTTER ENVIRONMENTS
- LOWER LRU COST (OPTIONS 3-5 APPROXIMATELY $300K)
- LOWER LIFE CYCLE COST
- IMPROVED RELIABILITY - ELIMINATION OF ONE HYBRID PER CHANNEL
- FUNCTIONALLY INTERCHANGEABLE WITH PRIOR-CONFIGURATION MODULES

46A/6-13

HYBRIDIZED LPRF FUNCTION

(VECP 260 & EFF. RADAR SET 57)

- COMBINES LPRF DIGITAL AND ANALOG MODULES INTO A SINGLE LPRF MODULE
- FOUR HYBRID CIRCUITS/72 DISCRETES REPLACE 380 DISCRETE COMPONENTS
- HYBRID DESIGN REDUCES NUMBER OF SELECT COMPONENTS, SIGNIFICANTLY DECREASING MODULE ALIGNMENT/TEST TIME
- IMPROVED RELIABILITY DUE TO REDUCED MODULE/PART COUNT
- SIGNIFICANT SAVINGS IN MANUFACTURING & LIFE-CYCLE-REPAIR COSTS
- FUNCTIONALLY INTERCHANGEABLE WITH PRIOR CONFIGURATION

46A/6-52

EXCITER T.O. AND L.O. MODULES GUNN VCO

(VECP 394, EFF. RADAR SET 127)

X-BAND GUNN DIODE OSCILLATORS INCORPORATED TO REPLACE MULTIPLIER CHANGE PLACE MULTIPLIER CHAINS

- IMPROVED PRODUCIBILITY AND OVERHAUL PROCEDURES
- IMPROVED RELIABILITY
- IMPROVED MAINTAINABILITY (FROM MTTR OF 70 HOURS MINIMUM TO MTTR OF LESS THAN 15 HOURS)
- LOWER LRU COST (THROUGH OPTION 5 AND FY 77 - FY 79 APPROX. $6.4M)
- SIGNIFICANTLY LOWER LIFE-CYCLE COST

24K SOLID STATE MEMORY

(VECP 522, EFF. RADAR SET 334)

REPLACED 16K WORD MAGNETIC CORE MEMORY SYSTEM OF THE RDP (081 LRU) WITH 24K SOLID-STATE EAROM MEMORY SYSTEM

- INCREASED MEMORY (16K TO 24K PLUS 2K SCRATCHPAD)
  - GROWTH CAPABILITY FOR IMPROVED RADAR SOFTWARE CAPABILITIES (UP TO 48K)
  - NDRO vs DRO MEMORY
  - IMMUNITY TO NOISE-INDUCED MEMORY ALTERATIONS
- LOWER LRU COST - (FY 77-79 APPROX. $5.2M)
- LOWER LIFE-CYCLE COST (APPROX. $1.6M FOR 24 SQUADRONS/10 YRS)
- RELIABILITY IMPROVEMENT OF 2:1

REDUCTION OF 928756 TRANSISTOR STRESS

(CCP 587A; EFFECTIVE RADAR SET 334)

- POWER SUPPLY IMPROVEMENT TO TRANSMITTER (011 LRU)

  RADAR DATA PROCESSOR (081 LRU) AND LOW VOLTAGE POWER SUPPLY (610 LRU) TO REDUCE 928756 TRANSISTOR STRESS

  - RESISTOR ADDED TO DAMPEN TURN-ON OVERSHOOT (+270V LINE)
  - INVERTER FLUX FEEDBACK RESISTOR ADDED TO PREVENT OSCILLATOR STUTTER
  - LIMITED STARTING CURRENT AND REDUCED STEADY-STATE CURRENT
  - IMPROVED FUSE ASSEMBLY
  - IMPROVED RECYCLING OF 610 LRU
  - ADDED RELAY AND UPGRADED TO NEW IMPROVED RELAYS FOR IMPROVED CIRCUIT PERFORMANCE DURING STEADY STATE OPERATION AND FOR ADDITIONAL CONTACTS REQUIRED TO ELIMINATE THE DROP ACROSS CRI
  - CIRCUIT ADDED TO THE 10A1 MODULE FOR IMPROVING BIT - BIT MONITORING OF AZ/EL AND GUARD/DIFFERENCE CHANNEL SELECT SWITCHES OF THE ANTENNA 031 LRU
  - MAJOR RELIABILITY IMPROVEMENT

46A/6-55

REPLACE PARAMP: COMBINE MIXER - PREAMP/IF AMP MODULES

(VECP 476A; EFFECTIVE RADAR SET 399)

- REPLACED THE PARAMETRIC AMPLIFIER MODULE (5AR2) WITH DUAL-CHANNEL FET RF AMP
- REDUCED MODULE COUNT BY COMBINING MIXER-PREAMP (5AR2) AND IF AMPLIFIER 5AR1 INTO ONE MODULE
- PERFORMANCE IMPROVEMENTS:
  - APPROX. 20% IMPROVEMENT IN HPRF CLUTTER-FREE ANGLE TRACKING RANGE
  - IMPROVEMENTS IN HPRF AND MPRF FALSE ALARM PERFORMANCE
  - IMPROVED MPRF CLUTTER REJECTION
- RELIABILITY - APPROX. 70% IMPROVEMENT OF MTBF OF AFFECTED MODULES
- LRU WEIGHT REDUCTION - APPROX. 1.5 LB
- LRU INTERCHANGEABLE WITH PREVIOUS CONFIGURATION
- LOWER LRU COST - APPROX. $8M FOR FYs 77-80
- SIGNIFICANT LIFE-CYCLE COST SAVINGS

COMBINE TEN MODULES INTO FIVE

(041 LRU)

(VECP 531; EFF. RADAR SET 399)

REDESIGNED TIMING AND CONTROL (T&C), DAGC, AND TARGET PARAMETER PROCESSOR (TPP) FUNCTIONS

- UTILIZATION OF LARGE CAPACITY PROGRAMMABLE ROMs
- UTILIZATION OF SCHOTTKY HIGH SPEED MSI
- REDUCED PARTS COUNT (BY 500 ICs)
- INCREASED SPARE MODULE SPARES (FROM 8 TO 13 FOR FUTURE GROWTH)
- REDUCED LRU WEIGHT - (2 LB)
- SLIGHTLY LOWER POWER CONSUMPTION AND HEAT DISSIPATION
- LOWER LRU COST (FY 77 THROUGH FY 80 - APPROXIMATELY $5M)
- LOWER LIFE-CYCLE COST (APPROXIMATELY $1M FOR 24 SQUADRONS FOR 10 YEARS)
- IMPROVED RELIABILITY (50% FOR T&C, DAGC, AND TPP FUNCTIONS)
- NO TACTICAL/SELF-TEST SOFTWARE CHANGES REQUIRED
- FUNCTIONALLY INTERCHANGEABLE WITH PRIOR CONFIGURATIONS
- EXTENSIVE COMPONENT EVALUATION/ALTERNATE SOURCE DEVELOPMENT BEFORE DESIGN FINALIZATION
- VERIFICATION OF DESIGN BY SUBJECTING ENGINEERING PROTOTYPE HARDWARE TO TEMPERATURE AND SYSTEM-LEVEL PERFORMANCE TESTS

46A/6-14

SIMPLIFY 039 LRU (7A2/7A3 MODULES)

(VECP 532A; EFF. RADAR SET 464)

REDESIGNED ANALOG SIGNAL PROCESSOR VCO CONTROL LOOP - REPLACED A/D CONVERTER MODULE, AND DETECTOR AND FREQUENCY CONTROL MODULE WITH NEW MODULES

- SIMPLIFIED CIRCUITRY WITH FEWER HYBRIDS
- LOWER LRU PRODUCTION COST (EST. $3.9M FOR MID-FY 77 TO MID FY-80)
- LOWER LIFE-CYCLE REPAIR COST (EST. $1.2M FOR 24 SQUADRONS OVER 10 YRS)
- IMPROVED RELIABILITY
- IMPROVED MAINTAINABILITY
- IMPROVED PRODUCIBILITY

PROGRAMMABLE SIGNAL PROCESSOR (042)

(RCP 613, EFF. RADAR SET 561)

I. MAJOR HARDWARE CHANGES AND HIGHLIGHTS

042 PSP - REPLACED HARD-WIRED PROCESSOR (041)

- FLEXIBILITY FOR GROWTH/CHANGES BY SOFTWARE ONLY
- GREATLY IMPROVED PROCESSING SPEED
- INCREASED BULK MEMORY
- IMPROVED TRANSIENT PROTECTION
- SHORT RELOADING TIME
- NO AIRCRAFT CHANGES REQUIRED TO REPLACE 041 (EXCEPT FOR COOLING ORIFICES)
- UTILIZATION OF COMMON MODULES FROM OTHER PROGRAMS
- SPARE MEMORY CAPACITY

081 RDP - INCREASED MEMORY CAPACITY (24K TO 96K)

REPLACED 4K EAROMs WITH MORE RELIABLE 8K EAROMs

PROGRAMMABLE SIGNAL PROCESSOR (042)
(RCP 613, EFF. RADAR SET 561)
(CONTINUED)

II. SOFTWARE MODE IMPROVEMENTS

- IMPLEMENTED ALL AIRVAL IMPROVEMENTS
- NEW RAID ASSESSMENT (RAM) MODE
- VARIABLE GROUND MOVING TARGET MODE
- AZIMUTH STABILIZED DISPLAY
- TWO NEW ECCM FEATURES
- HIGH RESOLUTION GROUND MAP MODE

46A/6-16

DESIGN FEATURES

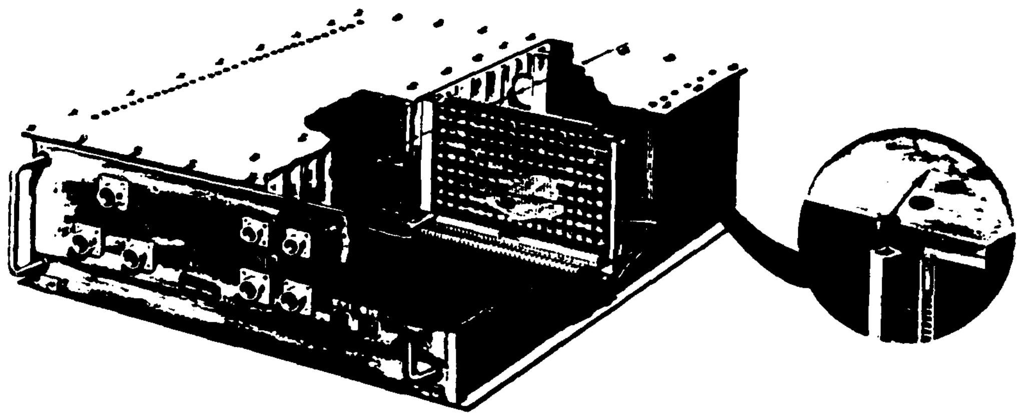
46A/6-17

TYPICAL APG-63 RADAR THERMAL DESIGN

Typical junction temperatures are lowered by 15°C compared to conventional methods through the use of highly efficient cross-flow heat exchangers built into each circuit board module. Cooling air enters the unit through the inlet in the back and flows down a center plenum to the tubular manifolds on the side of each module. The air then flows across the heat exchanger fin stock to the tubular exit manifolds and exits out the bottom of the unit (example is shown upside-down). The circuit boards are bonded to each side of the heat exchanger fin stock to provide a very short thermal conduction path from the electronic components to the cooling air.

F-15 APG-63 RADAR THERMAL DESIGN

- CENTRAL AIR PLENUM DISTRIBUTES AIR TO ALL MODULES
- COOLING AIR DOES NOT CONTACT COMPONENTS DIRECTLY
- COMPONENT TEMPERATURES REDUCED



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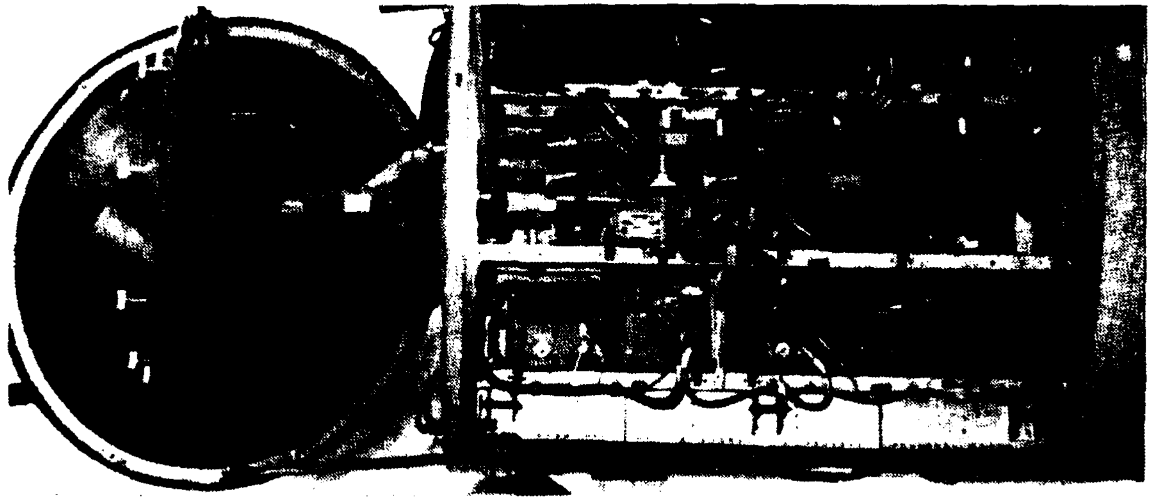
MAINTENANCE FEATURES

The following is a summary of the maintainability design features of the APG-63 radar system for each level of maintenance:

- Organizational Level: All system LRUs are installed in a functional group with easy access. The antenna is mounted inside the radome that is easy to open and close. All other LRUs, except the radar set control, are installed behind the radar equipment bay door that has quick release fastening devices. The radar set control is installed in the cockpit console with quick release fasteners and an electrical connector. All LRUs are installed with mounting hardware, hydraulic connections and electrical connectors that can be released and secured quickly and easily.

- Intermediate Level: LRUs have been designed with the advanced BIT circuits and to be compatible with Intermediate Level test stations. Access covers have quick-release fasteners, and circuit cards have guides and extractors for ease of replacement. Avionics Intermediate Shop (AIS) test stations used are:
  - Microwave Test Station
  - Displays Test Station
  - Indicator and Controls (I&C) Test Station
  - Antenna Test Station

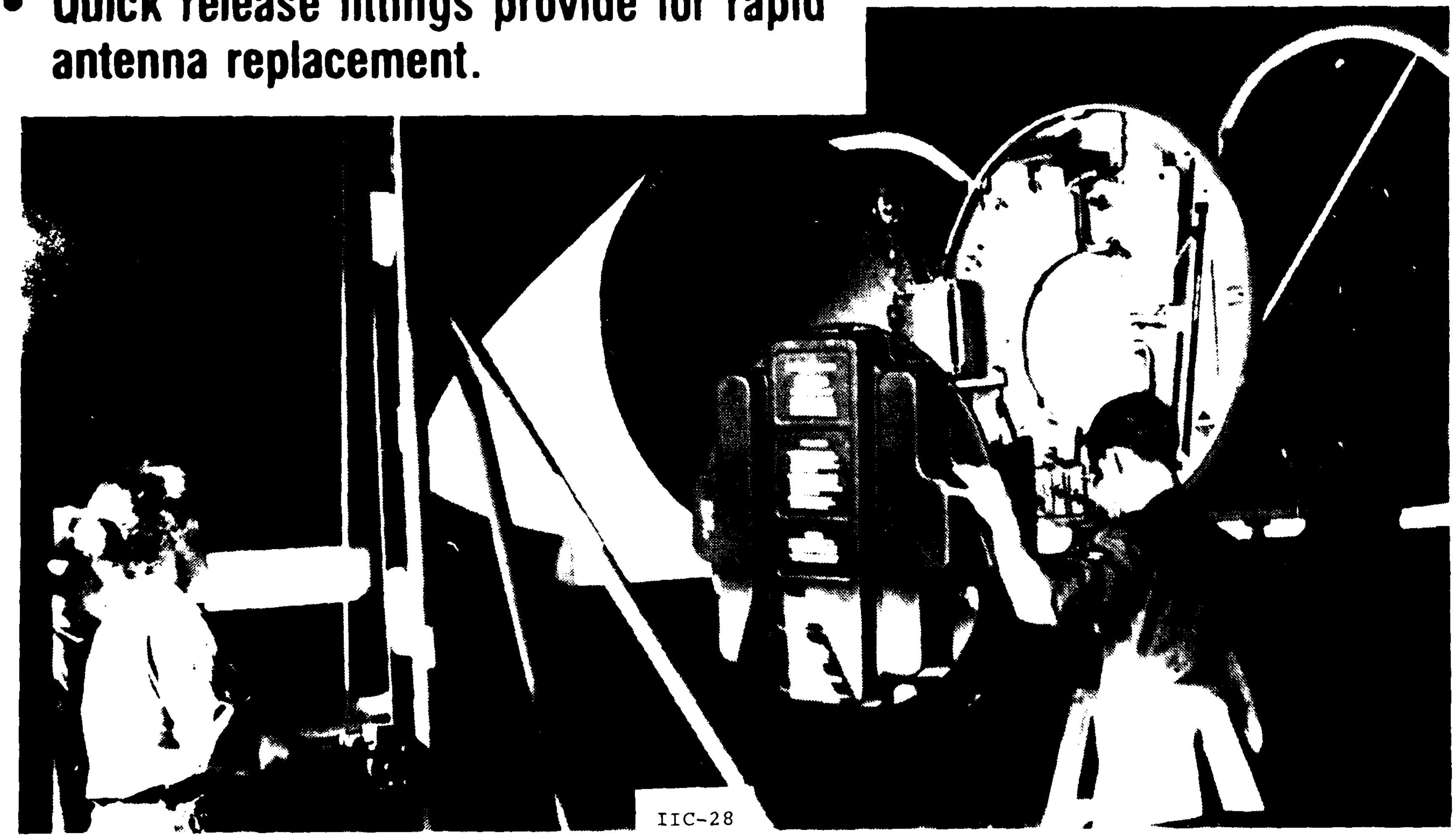
- Depot Level: SRUs are designed to be tested on Depot Level Test Stations.
  - Digital Avionic Depot Test Station
  - If-Video/Microwave Avionic Depot Test Station
  - Analog Avionic Depot Test Station
  - High Voltage/High Power RF Avionic Depot Test Station
  - DTS-70 Test Station.



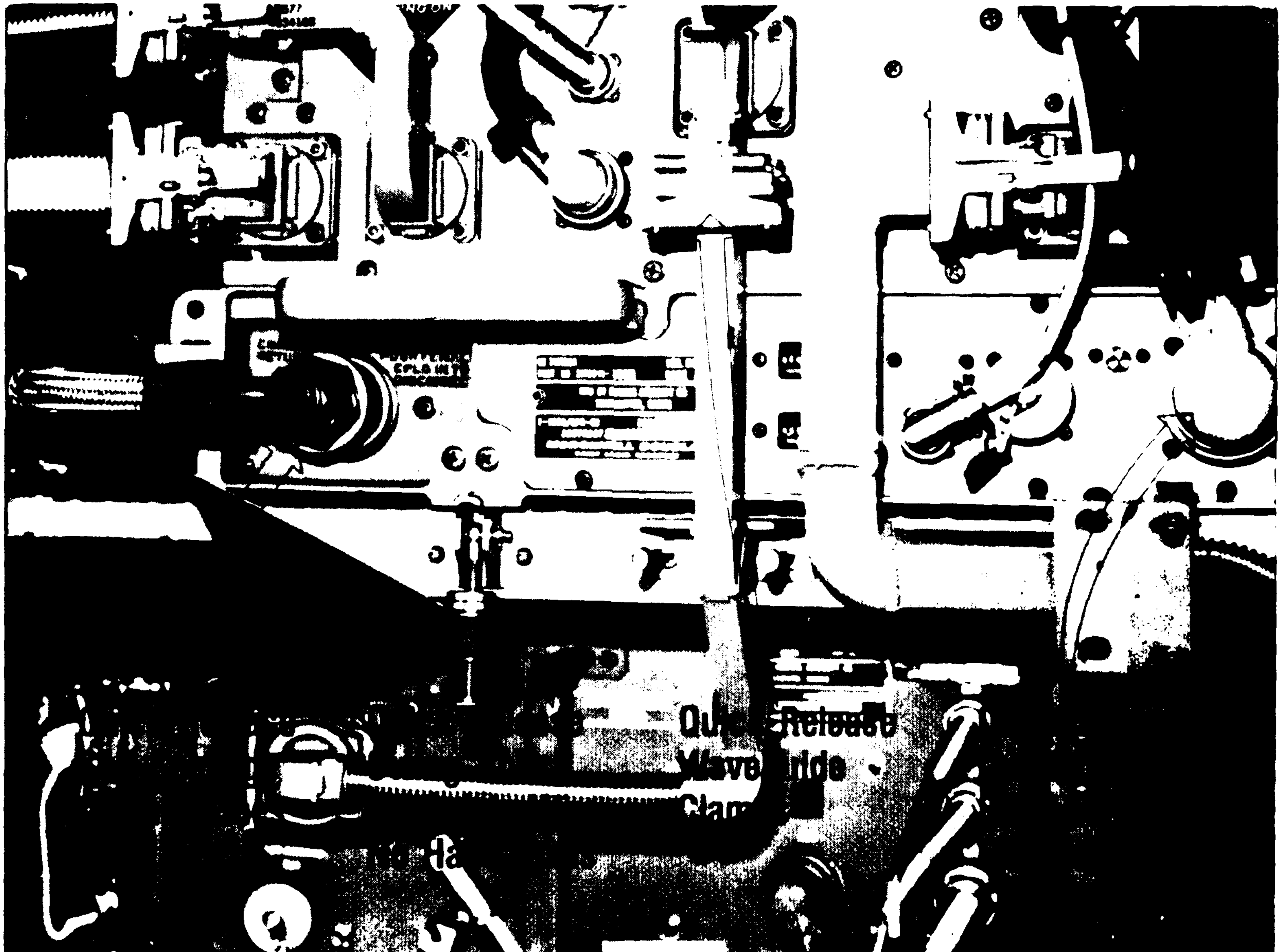
- Fire control system located in two equipment bays.
- Door and radome have built-in struts.
- Quick release disconnects for:
  - Hydraulic lines
  - Coolant lines
  - Waveguide Pressurization line
  - Waveguide segments
- Fire control system has keying baskets provided on coax connectors to prevent improper installation.

RADAR ANTENNA REPLACEMENT

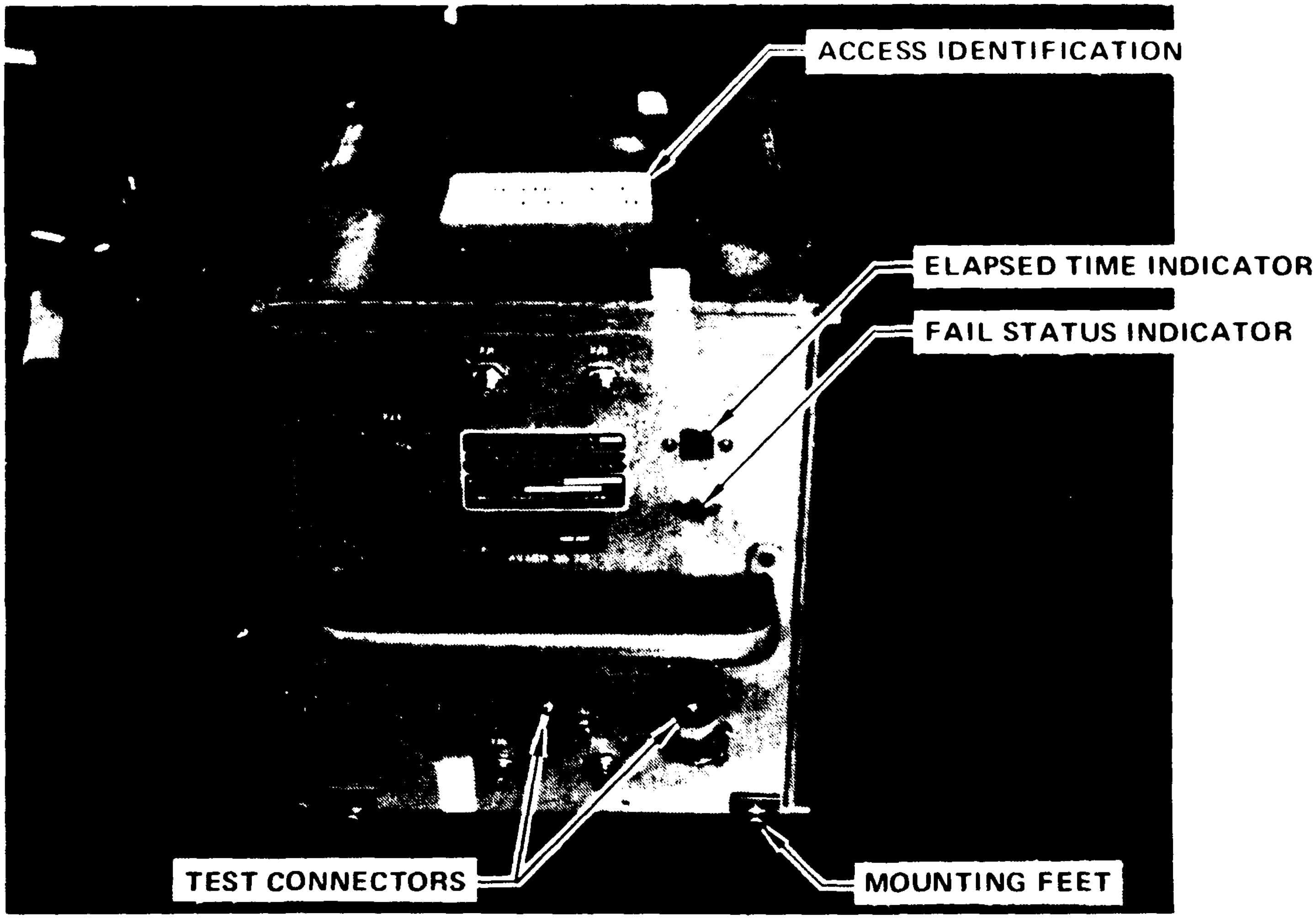
- Radome is opened only to facilitate antenna maintenance.
- Quick release fittings provide for rapid antenna replacement.



IIC-28



RADAR TARGET DATA ANALOG PROCESSOR



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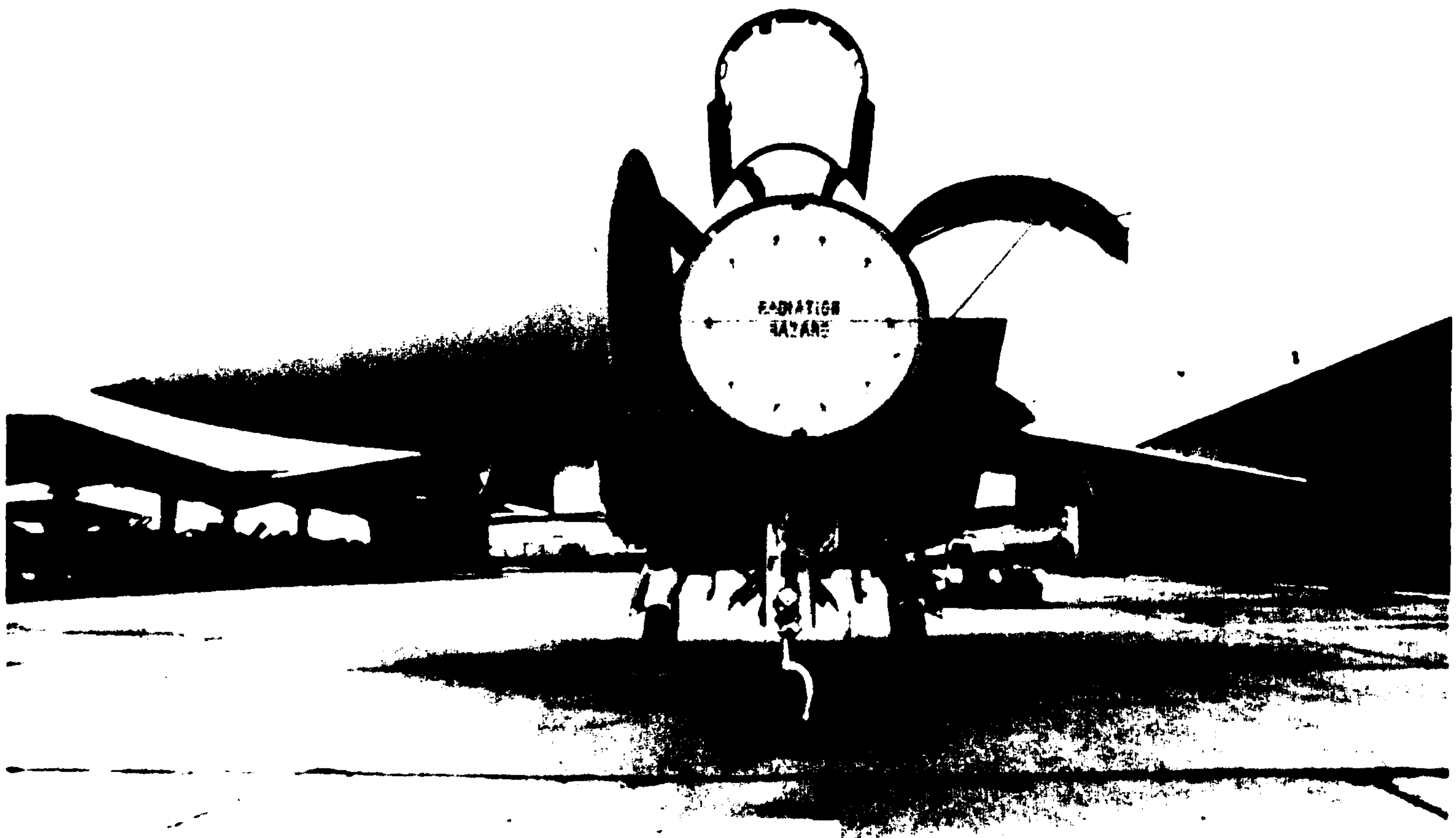

RADIATION
HAZARD

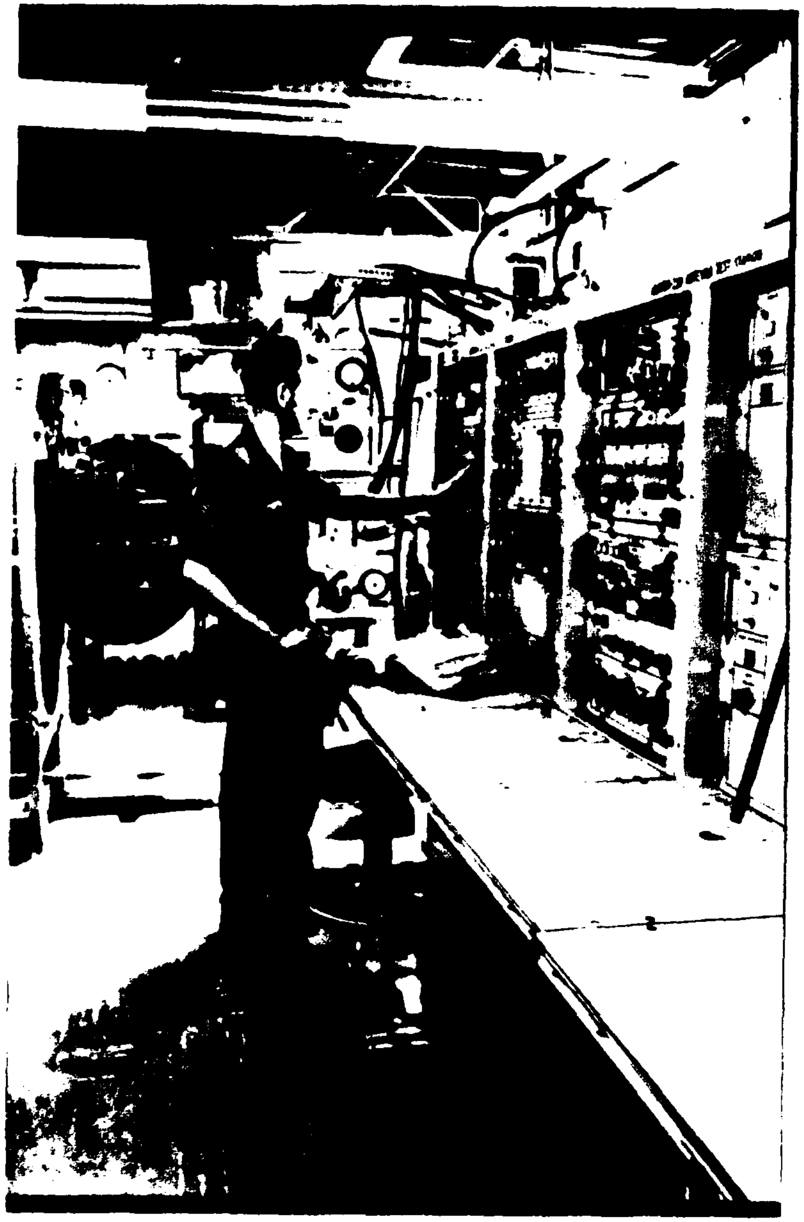
<u>Organizational Level</u>

- Fault isolate using BIT and operational test to determine faulty LRUs or associated aircraft wiring/connector(s).
- Remove and replace faulty LRUs and repair associated wiring/connectors.
- Test using BIT and operational test.


98%
Majority
Avionic equip prevent congestion of work
areas.
hold the avionic doors in the open position.

Intermediate Level

- Fault isolate LRUs using test program and appropriate intermediate level test station to determine faulty SRU, chassis mounted part(s) or wiring/connector(s).
- Remove and replace faulty SRUs, parts and repair wiring/connectors as required.
- Perform functional test.



AVIONIC INTERMEDIATE SHOP (AIS)

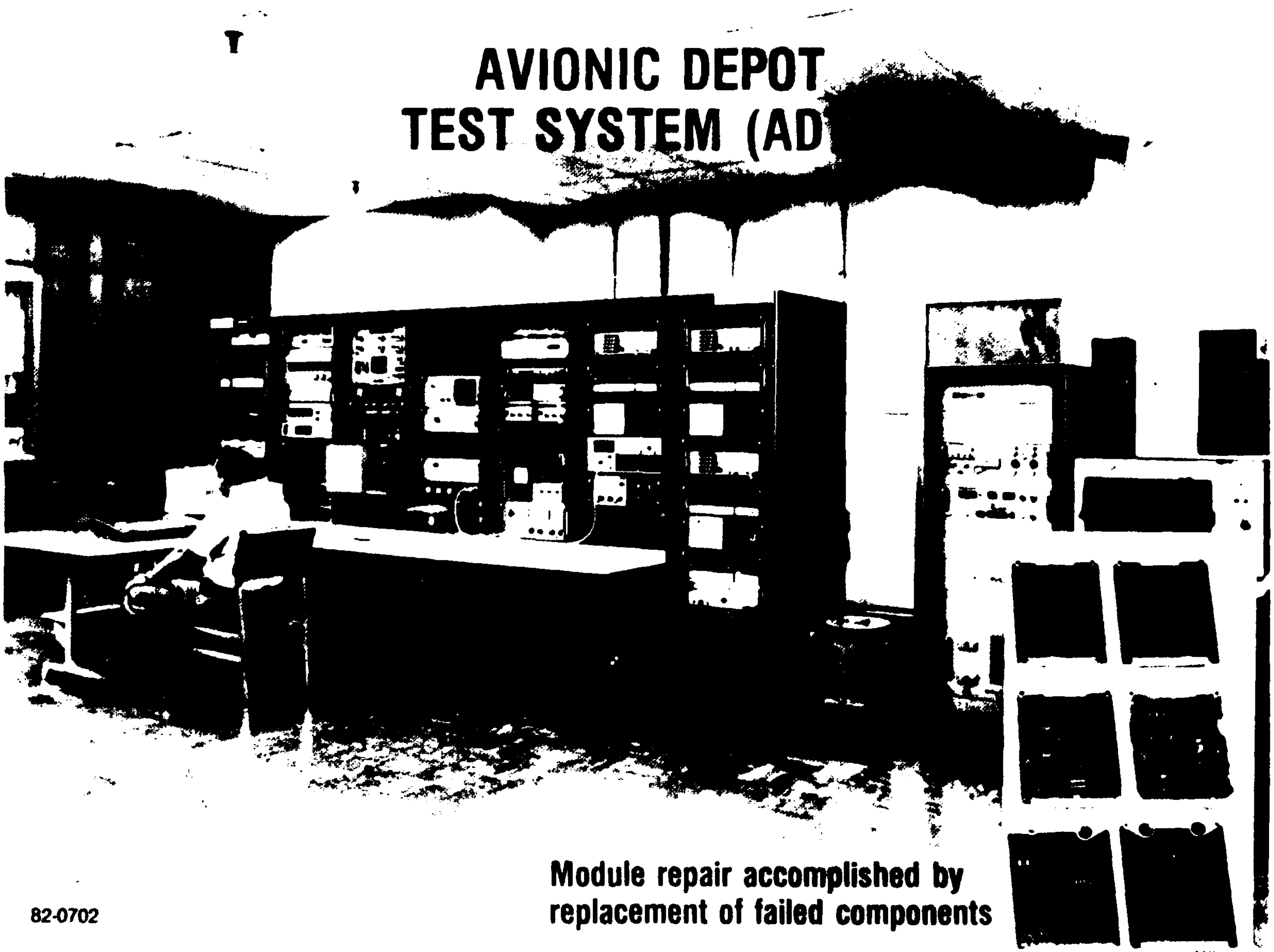
- Automatic testing and computer control provides fast, accurate testing
- The operator is the "Boss", the station does the work
- Protective devices safeguard people and equipment

46B/3-6

MAINTENANCE CONCEPT

<u>Depot Level</u>

- Fault isolate SRUs using test program and appropriate Depot Level test station to determine defective component(s).
- Completely repair and refurbish.
- Perform functional test.


AVIONIC DEPOT
TEST SYSTEM (AD
Module repair accomplished by
replacement of failed components
82-0702

F-15 MAINTENANCE DESIGN FEATURES IMPLEMENTED

SYSTEM LEVEL:

- NO AIRCRAFT ADJUSTMENTS INCLUDING NO ANTENNA BORESIGHTING
- NO PREVENTIVE MAINTENANCE
- BIT PLUS LRU FAULT INDICATORS ELIMINATE PLANE-SIDE TESTERS
- ALL CAPTIVE INSTALLATION HARDWARE
- ALL WAVEGUIDES USE QUICK-DISCONNECT COUPLINGS
- TRANSMITTER LIQUID COOLING AND ANTENNA HYDRAULIC FLUID LINES USE QUICK-DISCONNECT COUPLINGS
- ALL LRUs AND CONNECTORS ACCESSIBLE AND KEYED TO PRECLUDE IMPROPER CONNECTION
- LRUs REMOVABLE BY ONE MAN WITHOUT TOOLS (EXCEPT TRANSMITTER AND ANTENNA)

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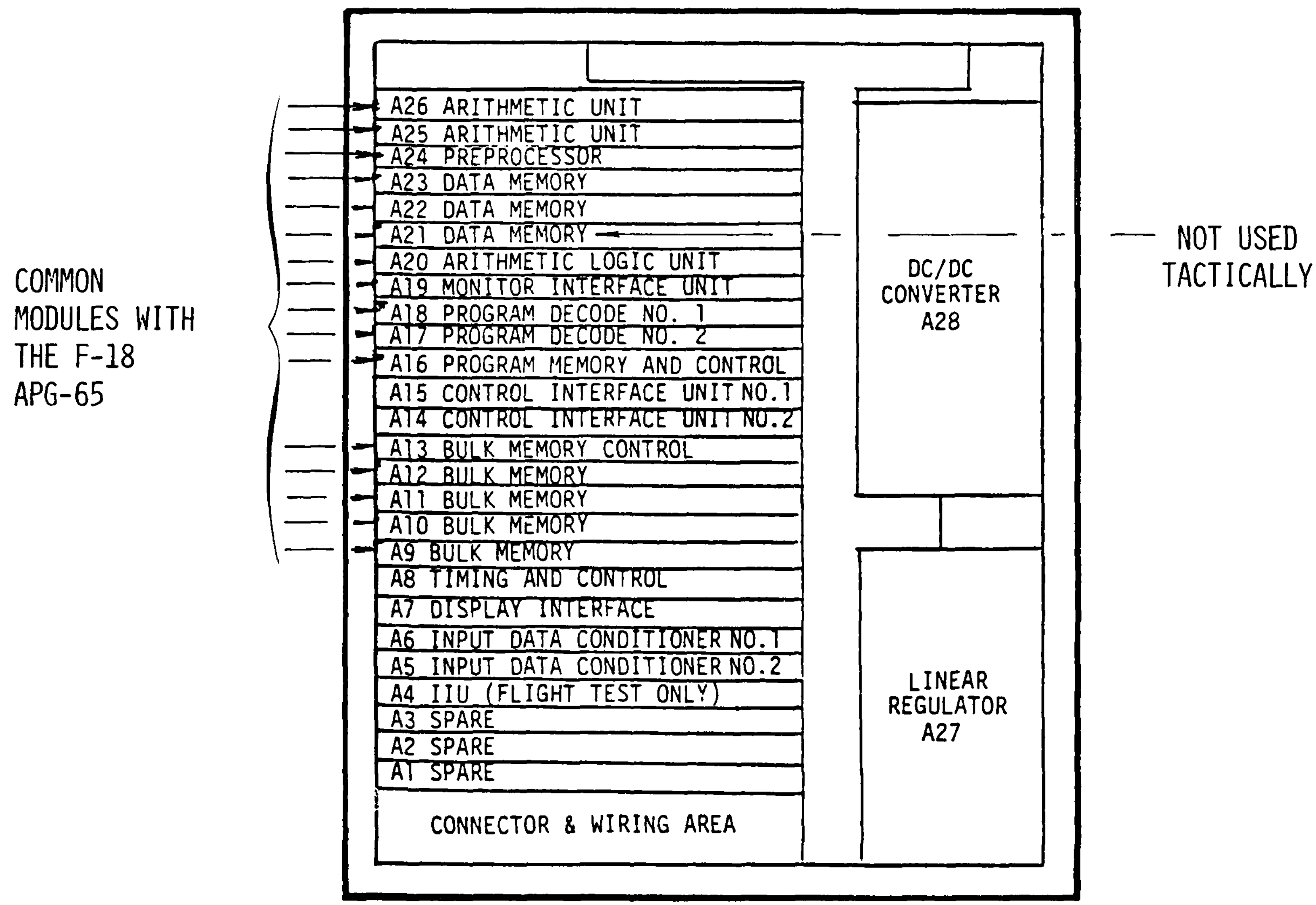
APG-63 PROGRAMMABLE SIGNAL PROCESSOR



THERMAL ANALYSIS

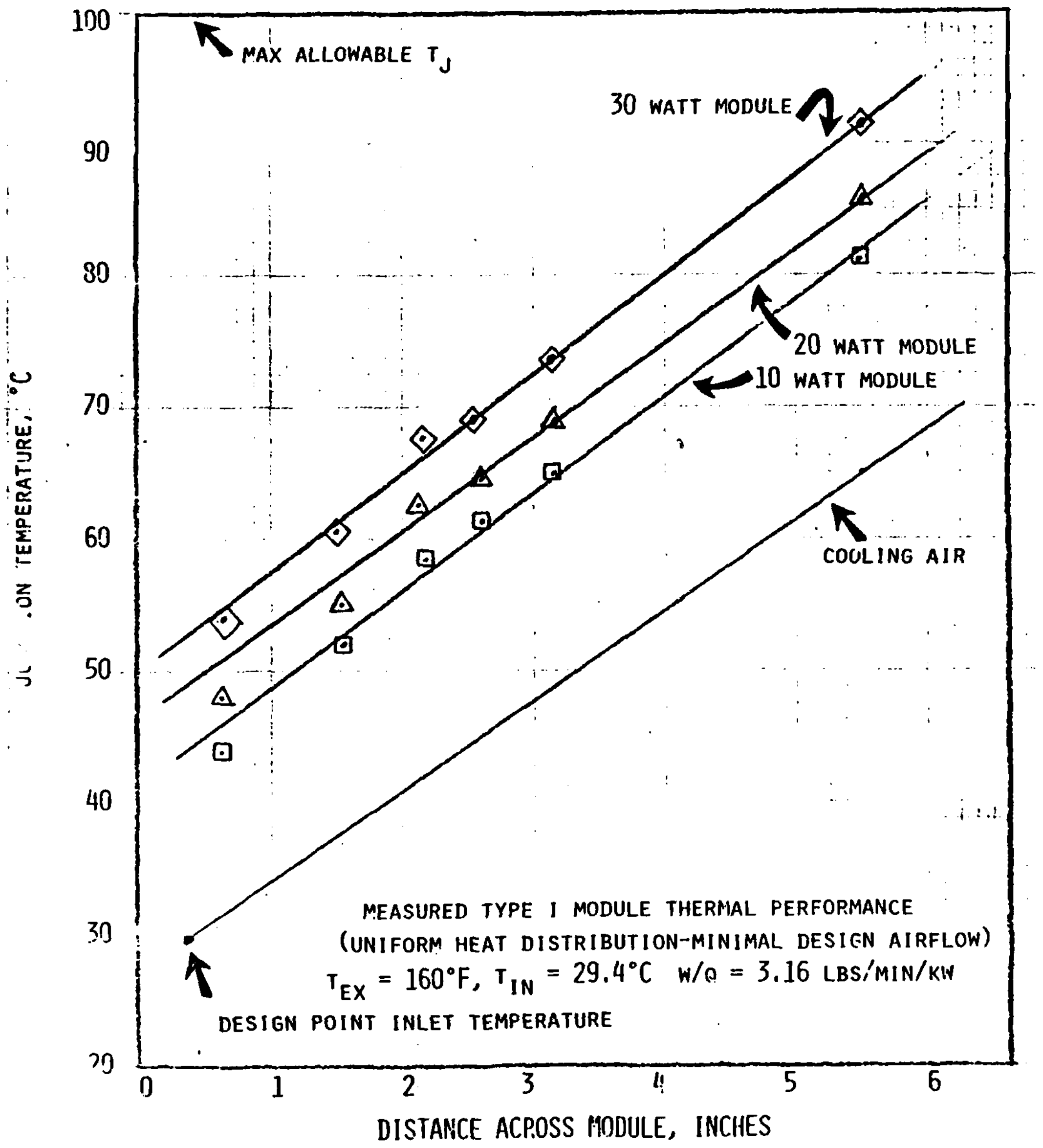
The F-15 Radar Set design specification required that microcircuit junction temperatures were not to exceed 100°C for component dissipations below 0.5 watts, and 105°C for components dissipating greater than 0.5 watts. This requirement was to be met for an exhaust temperature of 160°F (71°C), which occurs at the Minimum Design Flow Rate [Inlet temperature of 29.4°C (85°F) and W/Q - 3.16 lb/minute/KW], as well as for an exhaust temperature of 140°F (60°C), which occurs at the Nominal Design Flow Rate [Inlet temperature of 29.4°C (85°F) and W/Q - 4.31 lb/Minute/KW].

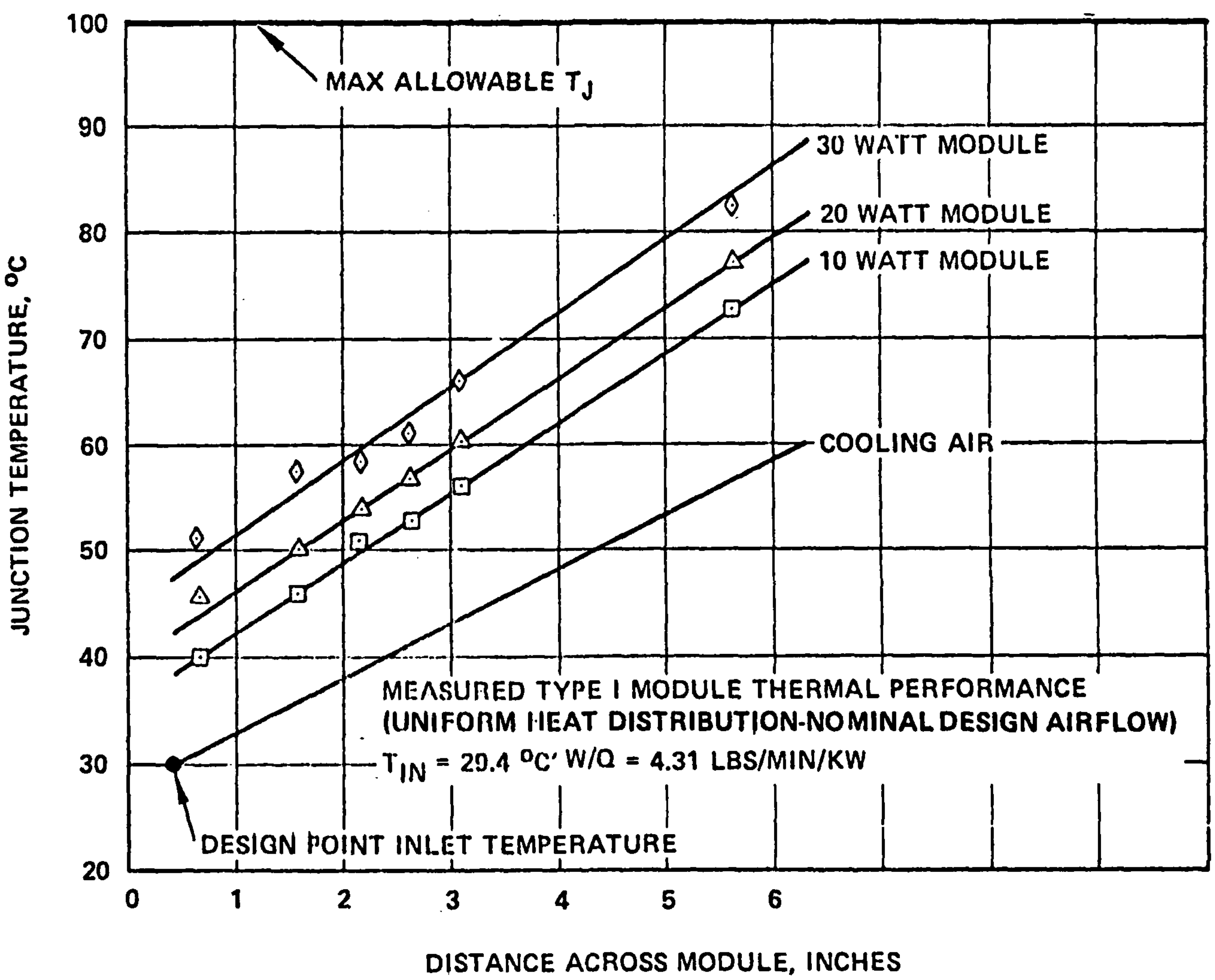
The results of the thermal design studies and analyses for the Nominal Design Flow Rate (exhaust air at 140°F) are presented on the graph on page IIC-44. The junction temperatures of parts located in the middle of the module are obtained where the curves (or lines) cross at an abscissa of 3 [this is the point at which average junction temperatures are quoted (i.e., for components located on the middle of the module equidistant from the inlet and exhaust air orifices]. The majority of the modules are 20-watt modules or less. There are very, very few 30-watt modules in the F-15 Radar Set. As such, Hughes normally quotes that the thermal analyses, corroborated by subsequent thermal surveys, revealed that average junction temperatures are on the order of 60°C.

The junction temperatures for components located on the module closest to the exhaust orifice are the rightmost data points on the graph on page IIC-44. For example, on a 10-watt module, $T_j \approx 72°C$; on a 20-watt module, $T_j \approx 77°C$; and on a 30-watt module, $T_j \approx 82°C$ for a component located on the module closest to the exhaust orifice.

Page IIC-43 is a graph of the results of the Thermal Design Studies and Analyses for Minimum Flow Rate [i.e., Exhaust air of 160° (71°C)]. With minimum design airflow, average junction temperatures on a 20-watt module are on the order of 68°C for components located in the center of the module. Junction temperatures for components located closest to the exhaust orifice are approximately 82°C, 87°C, and 92°C for 10-watt, 20-watt, and 30-watt modules, respectively.

THERMAL DESIGN





MAX ALLOWABLE T_J
30 WATT MODULE
20 WATT MODULE
10 WATT MODULE
COOLING AIR
MEASURED TYPE I MODULE THERMAL PERFORMANCE
(UNIFORM HEAT DISTRIBUTION-NOMINAL DESIGN AIRFLOW)
T_{IN} = 29.4 °C' W/Q = 4.31 LBS/MIN/KW
DESIGN POINT INLET TEMPERATURE
JUNCTION TEMPERATURE, °C
100
90
80
70
60
50
40
30
20
0
1
2
3
4
5
6
DISTANCE ACROSS MODULE, INCHES

- A steady-state thermal analysis computer program has been developed to evaluate the operating temperatures of the components in all of the module types. Use of the computer program has been streamlined for the Type I module so that the REA submits his component data on a standard data sheet and gets the results in a few days.

- If the computed component temperatures exceed the junction temperature of 100°C (105°C) the module layout is sent back for redesign. The typical modifications performed to optimize the thermal design are:
  (1) Redistribution of heat load
  (2) Relocation of high heat dissipating components near inlet air end of module
  (3) Reduce ΔT from component to cooling air by modifying component mounting interface.

- The module is analyzed again after modification to see if it meets the temperature requirements.

- Module design is not accepted until it meets the temperature requirements.

THERMAL DESIGN

COMPUTER ANALYSIS DATA

72.2	65.7	71.3		
37	38	39	40	
404	451	024	005	R
77	43	92	159	356
95	53	115	198	446
68.0	67.1	66.3	65.7	64
79.5	73.6	73.9		
49	50	51	52	
312	R	005	R	0
156	356	159	356	15
170	446	198	446	170
74.3	72.4	71.1	69.7	65.9
83.7				
61	62	63	64	
300	R	611L	611L	61
302	178	80	80	8
380	223	100	100	100
77.3	74.3	70.4	67.2	64.
98.1		82.4	78.2	76.
73	74	75	76	

MODULE NAME MEMORY CONTROLLER

RESPONSIBLE ENGR. C. H. MONT

TOTAL MODULE POWER (SIDE A+B) = NOMINAL
= HIGH NOM

DATE OF SUBMITTAL 1-6-71
DATE OF ANALYSIS ______

74.0	63.7	62.5		
37	38	39	40	
—	2R	005H	4R	4R
0	120	184	240	240
0	185	230	370	370
64.9	65.2	64.5	62.9	60.1
49	50	51	52	5
312	454	024	—	005H
136	35	92	0	184
170	44	115	0	230
67.6	65.5	63.9	61.3	60.
77.0	70.8	71.5		
61	62	63	64	
300	457	611L	611L	61
302	43	80	80	80
380	53	100	100	100
70.6	66.6	64.1	61.5	59
91.4	73.1	76.1	73.5	71
73	74	75	76	

MODULE NAME MEMORY CONTROLLER

RESPONSIBLE ENGR. C. H. MONT

TOTAL MODULE POWER (SIDE A+B) = NOMINAL
= HIGH NOM

DATE OF SUBMITTAL REV. A 1-20-71

DATE OF ANALYSIS ______

THERMAL DESIGN

- DIRECT AIR IMPINGEMENT VS. COLD PLATE DESIGNS VS. INTEGRAL MODULE HEAT EXCHANGER

INTEGRAL MODULE HEAT EXCHANGER SELECTED FOR DRAMATIC THERMAL PERFORMANCE IMPROVEMENT

	AVERAGE COMPONENT JUNCTION TEMPERATURE (T_J, ^oC)			
MODULE DISSIPATION (WATTS)	*DIRECT IMPINGEMENT	*CONVENTIONAL COLD PLATE	*F-15 INTEGRAL MODULE HEAT EXCHANGER	**F-15 INTEGRAL MODULE HEAT EXCHANGER (@ACTUAL NOMINAL COOLING)
5	73	73	67	
10	89	84	70	58
20	118	104	77	62
30	140	125	85	68
40	174	145	100	--

*DATA NORMALIZED TO COOLING AIR INLET OF 30^{o}C, EXHAUST OF 71^{o}C & Δ P OF 2 INCHES H_2O AT S.L. (W/Q = 3.16 LBS/MIN/KW)

**ACTUAL F-15 NOMINAL COOLING AIR FLOW OF W/Q = 4.31 LB/MIN/KW WITH EXHAUST TEMP = 140^{o}F

HIGH DENSITY PACKAGING:

SEVERAL CONVENTIONAL AND NEW PACKAGING CONCEPTS ANALYZED

FLAT PACKS, SURFACE MOUNTED DISCRETES, INTEGRAL MODULE HEAT EXCHANGERS AND CRUSHED HONEYCOMB ENCLOSURE WERE SELECTED FOR DRAMATIC IMPROVEMENTS OVER CONVENTIONAL DESIGNS

F-15 PACKAGING VS. CONVENTIONAL DESIGN

	MODULE CAPABILITY				LRU LEVEL CAPABILITY		
	NO. OF IC'S	WEIGHT (LBS)	DISSIPATION (WATTS)	COMPONENT T_J (^oC)	WEIGHT (LB^3/FT^3)	COMPONENTS (PER FT^3)	COMPONENTS (PER LB)
CONVENTIONAL	56	.2	10	125	17.6	3,950	125
F-15	168	.4	30	85	9.4	11,000	312

IMPROVEMENT FACTORS: COMPONENT T_J 1.5 TO 1, MODULE CONNECTORS 3 TO 1, VOLUME 2.8 TO 1, WEIGHT 2.5 TO 1

PRODUCT DESIGN ANALYSIS & TRADEOFFS (CONTINUED)

COMPONENTS	
• USE OF DIP'S & CONVENTIONAL MOUNTED DISCRETES VS. FLAT PACKS & SURFACE MOUNTED DISCRETES	FLATPACKS & SURFACE MOUNTED DISCRETES SELECTED FOR THEIR LOWER THERMAL IMPEDANCE, EASIER REMOVAL AND HIGHER PACKAGING DENSITY
STRUCTURAL DYNAMICS	
• RIVETED, WELDED & BRAZED SHEETMETAL VS. BONDED CRUSHED HONEYCOMB ENCLOSURE CONSTRUCTION	BONDED CRUSHED HONEYCOMB DESIGN SELECTED FOR BOTH LIGHT WEIGHT AND A REDUCED TRANSMISSIBILITY OF 3 TO 5 VS. APPROXIMATELY 20 FOR CONVENTIONAL DESIGNS

THERMAL DESIGN

FORCED AIR COOLING THERMAL REQUIREMENTS

PS 68-870011 SPECIFIES:

- BAY AMBIENT TEMPERATURE/ALTITUDE LIMITS - CONTINUOUS (NORMAL OPERATION) = 10°C TO 71°C/SL TO MAX ALT

  30 MINUTES (EMER. OPERATION)
  COLD = -54°C TO 10°C/SL TO MAX ALT
  HOT = 71°C TO 95°C/SL TO MAX ALT

  COLD/HOT STARTUP = -54°C/71°C

- AIR DELIVERY TEMPERATURE - NORMAL FLIGHT = 10°C TO 29.4°C
  AIRCRAFT STATIC = 10°F TO 40.6°C
  EMERGENCY FLIGHT = -54°C TO 57°C
  GROUND CHECKOUT = -54°C TO 40.6°C

- HEAT LOAD LIMITS - NORMAL OPERATE - WITH CWI = 3905 WATTS
  WITHOUT CWI = 3880 WATTS

- FLOW RATE LIMITS - NORMAL OPERATE - WITH CWI = 12.352 LB/MIN
  (MIN. DESIGN FLOW AT 85°F) WITHOUT CWI = 12.206 LB/MIN

- UNIT ΔP LIMIT - RADAR SIGNAL PROCESSOR UNIT $\leq$ 2.75 IN. H_2O (MAXIMUM)
  (AT DESIGN POINT) ALL OTHER UNITS $\leq$ 2.00 IN. H_2O (MAXIMUM)

THERMAL DESIGN

- COOLING AIR IS INTRODUCED AT UNIT REAR PANEL AND EXHAUSTED THROUGH BOTTOM COVER
- CENTRAL (OR SIDE) UNIT AIR PLENUM DISTRIBUTES AIR TO ALL MODULES IN PARALLEL
- AIR IS METERED BY ORIFICES IN MODULE INLET MANIFOLD
- INLET AND EXHAUST MANIFOLDS PROVIDE UNIFORM AIR FLOW THROUGH MANIFOLD BY ESTABLISHING EQUAL LENGTH FLOW PATH
- NO CONTAMINANT-LADEN COOLING AIR CONTACTS UNIT ELECTRONICS
- NORMALLY INSTALLED ORIENTATION PROVIDES SELF-DRAINING MODULE FEATURE UNDER HIGH COOLING AIR HUMIDITY CONDITIONS
- EXHAUST MANIFOLD ON OUTER SIDE OF UNIT MINIMIZES AMBIENT HEAT GAIN

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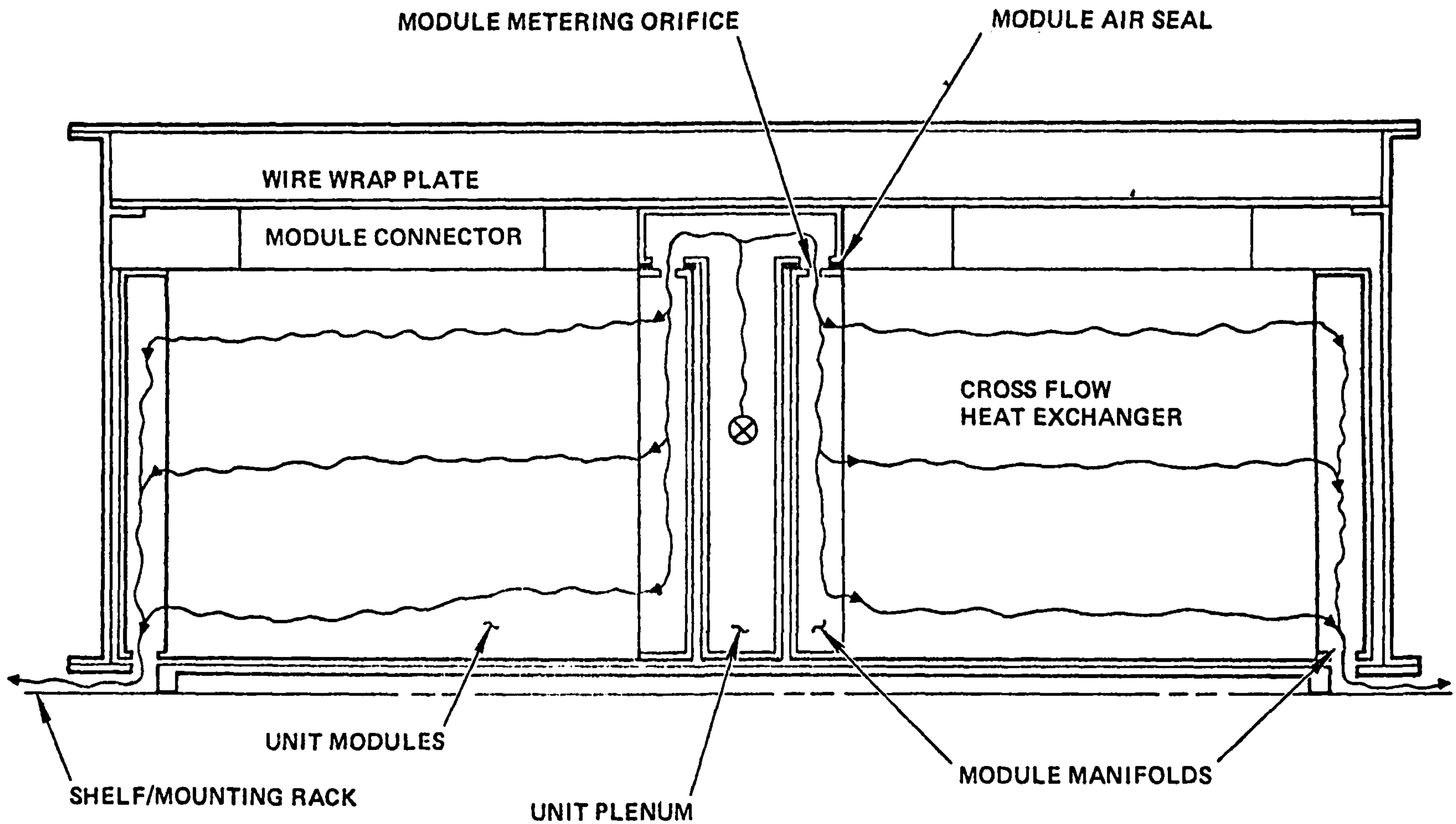
MODULE/UNIT COOLING IMPLEMENTATION



- All units have been designed with an overall ΔP equal to the specification limit and been verified by test using a representative mockup of each unit plenum.
- The plenum pressure distribution was measured for each unit with and without aircraft balancing orifices at their inlet.
- Sea level and altitude tests were conducted on the unit plenums which require high cooling air flow rates (041, 081, and 610) to verify that their distribution characteristics are adequate under all specified conditions.
- Plenums have been baffled to control the velocity head effect on pressure/flow distribution along their length.

THERMAL DESIGN

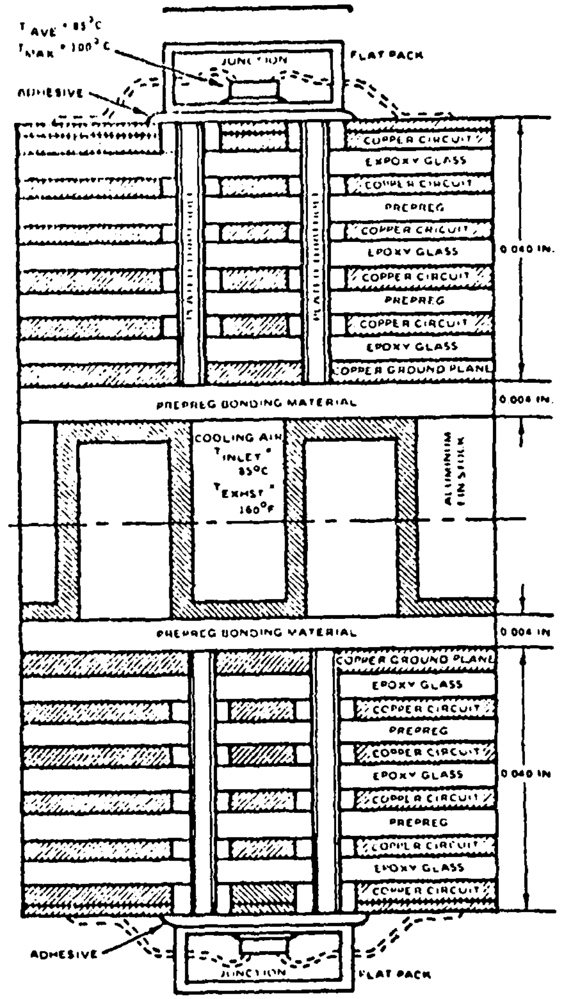
Cross-flow module design provides:

- Minimum length heat flow path
- Low mass, rapid thermal response characteristics
- Low pressure drop
- High efficiency heat exchanger

PRINTED WIRING BOARD MODULE

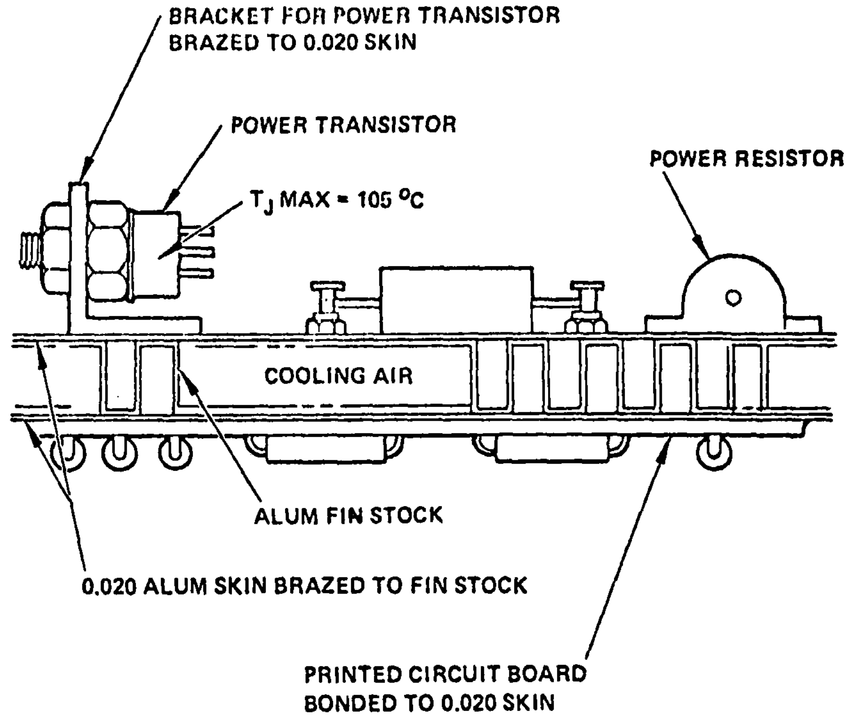
	TYPE I	TYPE III
FIN STOCK		
• HEIGHT (IN.)	0.075	0.150
• FPI	12	16
• OFFSET (IN.)	0.500	0.125
DISSIPATION-WATTS	34	55
MEASURED THERMAL DATA		
*• θ °C/WATT FLATPACK CASE TO COOLING AIR	48.1	48.1
• ΔP-IN. H_2O	1.91	1.50

* θ IS THERMAL IMPEDANCE TYPICAL AT Δ T FOR 1/4 WATT FLAT PACK IS 12°C



DIP BRAZED MODULE

	TYPE II			TYPE IV		
	A	B	C	A	B	C
FIN STOCK						
• HEIGHT (IN.)	0.150	0.250	0.500	0.150	0.250	0.500
• FPI	16	16	16	16	16	16
OFFSET (IN.)	0.125	0.125	0.125	0.125	0.125	0.125
DISSIPATION-WATTS	40	65	215	115	200	215
THERMAL DATA						
Θ - °C/WATT COMPONENT CASE TO COOLING AIR	6.4	5.2	3.7	3.7	3.2	2.9
ΔP - IN. H_2O	1.23	0.87	1.65	1.66	1.07	1.07



- Component mounting design has been evaluated for all component types to provide optimum heat transfer at the mounting interface

- Polysulfides, acrylic adhesive tape, mounting clips, etc., are used where necessary to achieve the desired component operating temperatures

- The most widely used component mounting materials are those shown

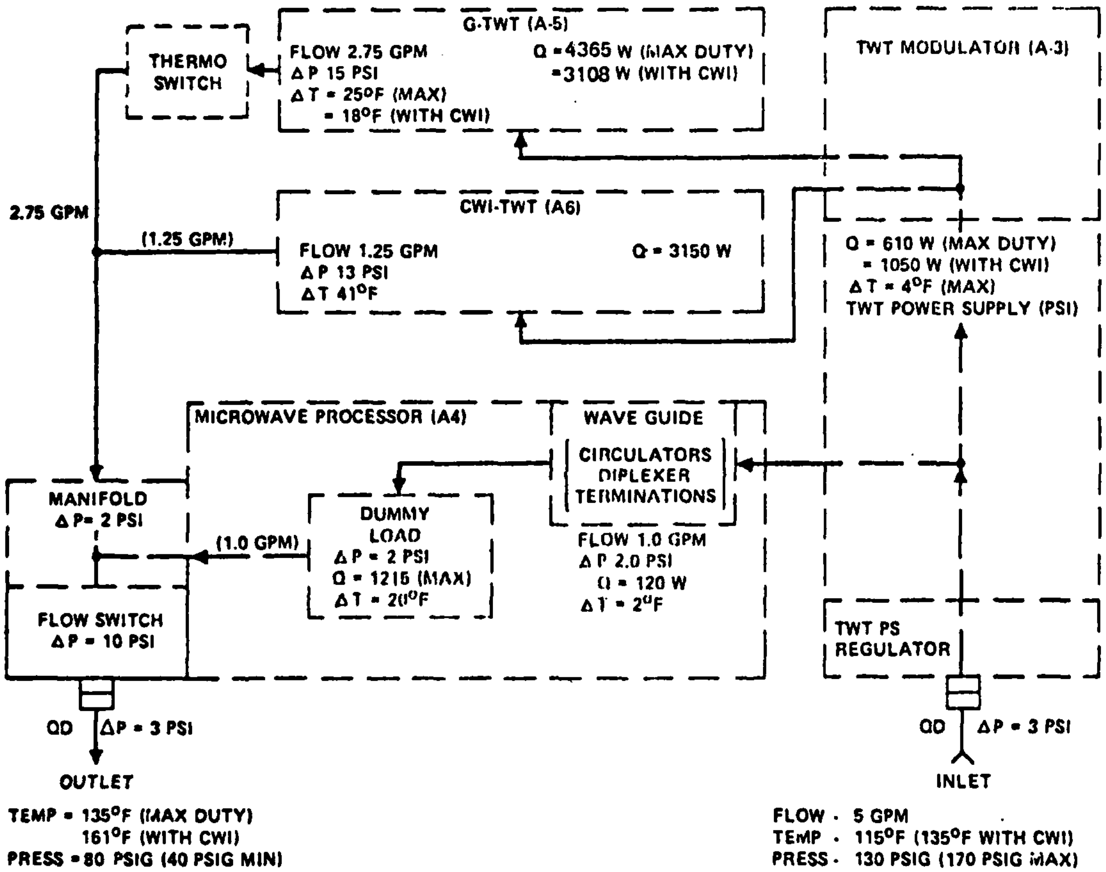
COMPONENT THERMAL INTERFACE		
COMPONENT TYPE	CONDUCTING MATERIAL	COMPONENT TEMP. RISE °C/WATT/SQUARE INCH
AXIAL LEAD	POLYURETHANE CONFORMAL COATING	5
AXIAL LEAD	POLYSULFIDE AND POLYURETHANE	4
AXIAL LEAD	POLYSULFIDE/ALUMINA AND POLYURETHANE	3
FLAT PACKS	ADHESIVE TRANSFER TYPE AND POLYURETHANE	1
HIGH POWER DEVICES	THERMAL WASHERS AND CLIPS	0.2 TO 0.3

THERMAL DESIGN DESCRIPTION
UNIT COOLING IMPLEMENTATION

- Liquid coolant is introduced into unit front panel and returns through the front panel via flexible coolant lines.
- Coolant lines attach with quick disconnect couplings.
- Coolant flows in a series - parallel circuit through the major component assemblies inside the unit. Coolant is metered by balancing orifices in the parallel branches.
- A flow switch does not allow the GTWT to turn on unless coolant flow is present.
- A thermal switch turns the GTWT off if the exhaust temperature gets too high. This may occur if the flow rate is low but still high enough to trip the flow switch.
- High voltage power supply immersed in coolant provides efficient cooling, light weight and excellent dielectric properties.
- High efficiency (copper) cooling fins in GTWT collector transfer heat to coolant.

THERMAL DESIGN

TRANSMITTER UNIT COOLING SCHEMATIC



UNIT THERMAL ANALYSIS RESULTS	
COMPONENT ASSY	OPERATING TEMP
TWT'S	COOLING FIN HOT SPOT IN COLLECTOR SECTION = 81°C
RF LOGIC MODULE IN MICROWAVE PROCESSOR	COMP JUNCTION TEMP < 100°C
PREPULSER MODULE IN MICROWAVE PROCESSOR	COMP JUNCTION TEMP < 100°C

Forced Air Cooling

• Unit Heat Dissipation (Final Values)	Per P.S. 68-870011 - Final unit dissipation values submitted to MCAIR in March 1, 1971 thermal characteristics report No. E-37-C.
• Unit and Module Air Allocated	Airflow allocations established from individual module dissipations.
• Module Heat Transfer Characteristics Established by Analysis and Test	Type I module thermal performance verified by tests. Type II, III, and IV module thermal performance determined by a computer thermal analysis. Will be verified by tests in April.
• Unit Airflow and Pressure Drop Characteristics - Established by Test	Airflow tests performed on all unit plenums to establish entrance ΔP, overall unit ΔP and pressure distribution inside plenum at S.L. and altitude with and without aircraft distribution orifices.
• Module Airflow and Pressure Drop Characteristics Established by Test	Airflow tests performed on all module types to establish overall module ΔP, manifold ΔP, and heat exchanger ΔP.
• MCAIR/HAC Cooling Interface Established and Agreed Upon	

46B/1-29

VIBRATION

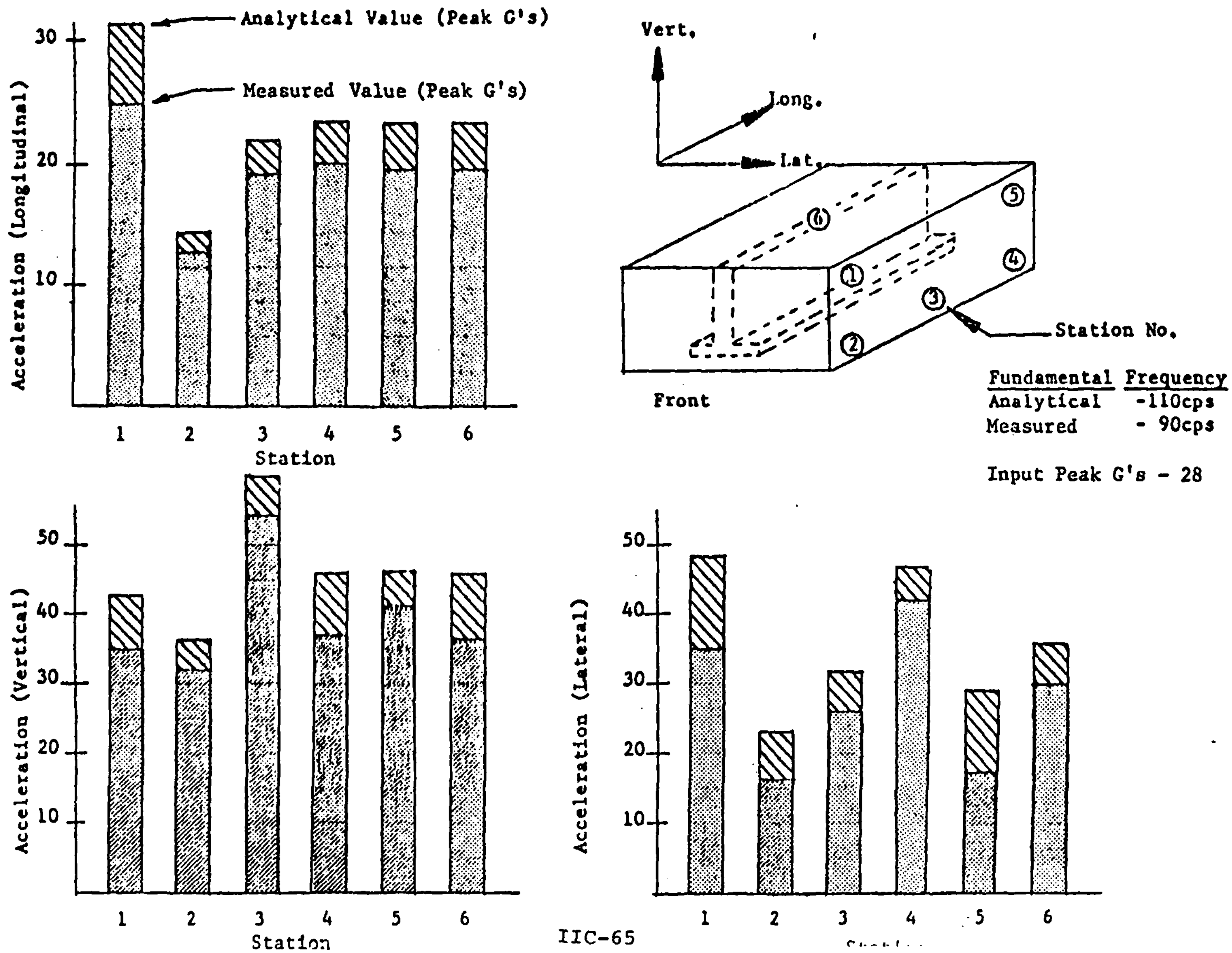
VIBRATION/TRANSMISSIBILITY

Vibration tests have been run at the specified operation level of 5.1 g's rms and the endurance level of 9.5 g's rms with a complete set of weighted modules representative of the 6.9-inch-high Radar Signal Processor Unit. The measured response values at the endurance level have been compared to the analytically predicted values to establish the validity of the computer model. As is illustrated, the test results show that the analytical predictions are reasonably accurate and somewhat conservative, and that the bonded honeycomb structure does have a low transmissibility.

During the tests, two failures occurred. The first was a fracture of a welded corner joint which, during fabrication, had been rewelded due to lack of adequate weld penetration. To avoid reoccurrence of potential welding problems, the corner has been redesigned to a bonded joint. Second, a mounting bushing worked loose in the rear panel of the unit. A design change has also been implemented to avoid reoccurrence of this problem.

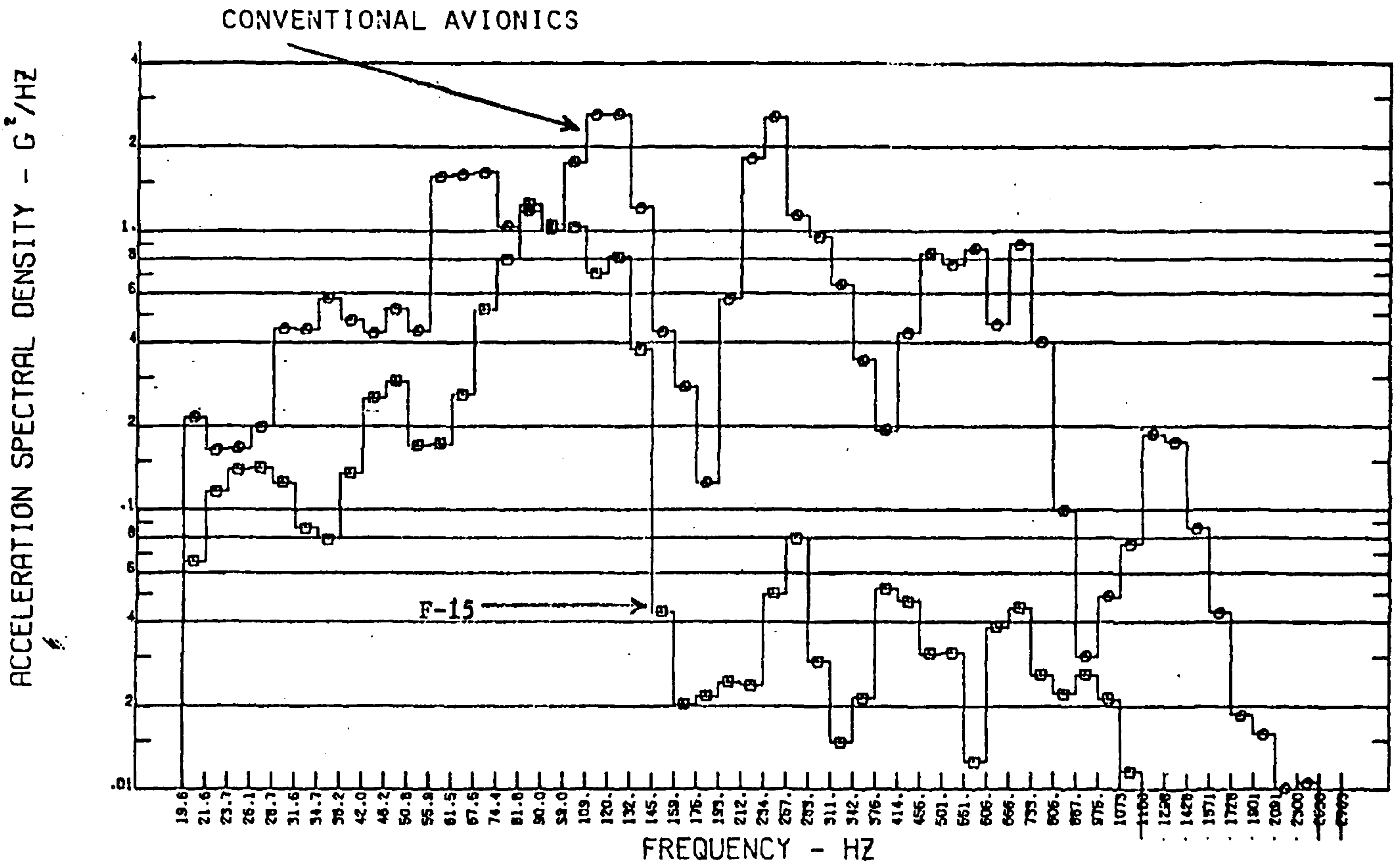
Dynamic Response Peak G's

(Radar Signal Processor)



VIBRATION/TRANSMISSIBILITY

LRU CHASSIS RESPONSE



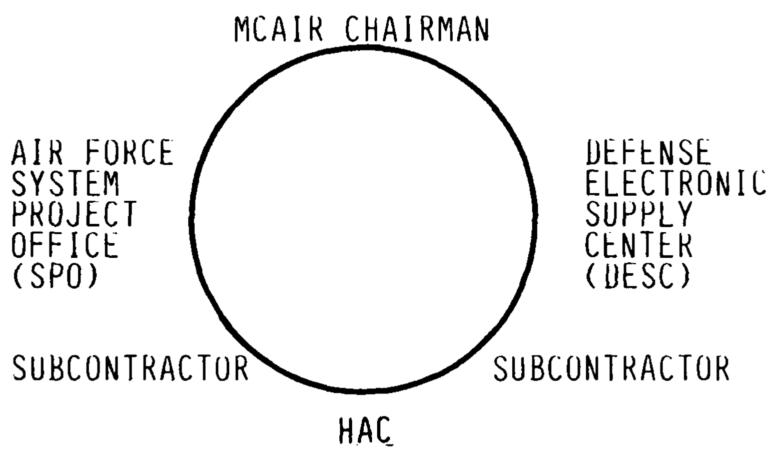
PARTS AND MATERIAL CONTROL

46A/6-20

PARTS CONTROL BOARD

For the F-15, parts standardization and control was recognized as a key factor in reducing costs and achieving the high reliability requirements that had been specified. A parts control board was established which MCAIR chaired with participation from major subcontractors, the F-15 SPO, and DESC. This board established a Preferred Parts List (MCAIR Report A095) with mandatory usage by MCAIR designers as well as subcontractors. The first integrated circuit sheets to MIL-STD-883 were prepared by this board and their release was then expedited by DESC. These actions and methods were the model for later aircraft programs and MIL-STD-965, Parts Control Program, which was issued in 1977.

F-15 PARTS CONTROL BOARD TASKS



- PARTS SELECTION FOR PPL
- PREPARE MILITARY PROCUREMENT SPECS
- PARTS/SUPPLIER EVALUATION
- PARTS INFO/PROBLEM SOLUTIONS
- PCB INFO BULLETINS

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F-15 APG-63 PARTS PROGRAM

A parts program for all F-15 CFE design was established in the reliability program plan and implemented by specific requirements in the procurement specification. Control was exercised by MCAIR review and approval of the parts list submitted by HAC, with justification and adequate procurement documentation required for proposed non-standard parts, i.e., any part not listed on the preferred parts list coordinated by the Parts Control Board.

F-15 APG-63 PARTS PROGRAM

- PREFERRED PARTS LIST DEVELOPED AND MAINTAINED
- ESTABLISHED RELIABILITY PARTS PREFERRED
- JAN-TX SEMICONDUCTORS PREFERRED
- HIGH RELIABILITY MICROCIRCUITS
    - STANDARDIZATION (MIL-M-38510 SPECS)
    - SCREENING (MIL-STD-883, CLASS B)
        - 168 HOURS BURN-IN AT 125°C
        - 10 CYCLES THERMAL SHOCK, -65°C TO 150°C
        - CENTRIFUGE TO 30,000 Gs
        - HIGH TEMPERATURE STORAGE, 150°C FOR 24 HOURS
        - GROSS AND FINE LEAK TESTS
        - INTERNAL VISUAL PRECAP INSPECTION
        - ELECTRICAL MEASUREMENTS

46A/1-64

IMPLEMENTED COMPONENT SELECTION & STANDARDIZATION PROGRAM

- PROGRAM INSTRUCTIONS ISSUED WHICH MANDATED:
  - PARTS SELECTION CONTROLS AND PROCEDURES
  - PARTS ELECTRICAL AND THERMAL DERATING CRITERIA
  - COMPUTERIZED MODULE INDENTURED PARTS LISTS UPDATED WEEKLY TO REVIEW AND CONTROL PARTS SELECTION FOR RELIABILITY AND STANDARDIZATION
  - COMPONENT LEAD BENDS, ASSOCIATED PWB ARTWORK PAD PATTERNS AND HEAT TRANSFER AIDS SPECIFIED IN ONE F-15 DESIGN DOCUMENT AND UNIVERSALLY APPLIED TO ALL MODULE DRAWINGS
  - THERMAL ANALYSIS TO ACHIEVE <100°C FOR LOW AND <105°C FOR HIGH DISSIPATION COMPONENTS EARLY IN THE DESIGN PHASE USING A COMPUTERIZED THERMAL MODULE AUGMENTED WITH A LIBRARY OF SELECTABLE PARTS CHARACTERISTICS AND THE SPECIFIC CHARACTERISTICS OF THEIR MOUNTING AND HEAT TRANSFER AIDS SO THAT ANY COMPONENTS EXCEEDING THE LIMITS COULD BE RELOCATED AND THE DESIGN OPTIMIZED FOR HIGH RELIABILITY WITHOUT IMPACTING COST AND SCHEDULE
- THE EARLY THERMAL ANALYSIS & TESTING COUPLED WITH THE NOMINAL COOLING AIR FLOW PROVIDING AN EXHAUST TEMPERATURE OF 140°F NEGATED THE NEED FOR LATER "THERMAL REDESIGN"

46A/6-59

STANDARD UNIT CONFIGURATION

UNIT	CARD FILES	MODULE TYPES	PLENUM	INTRACONNECTION
EXCITER 001	3	II	CENTRAL	HAND WIRED
RECEIVER 022	2	II	CENTRAL	HAND WIRED
RADAR SIG. PROC. 041	2	I & II	CENTRAL "L"	WIREWRAP
RADAR DATA PROC. 081	2	I & II	CENTRAL	WIREWRAP
ANALOG PROC. 039	1	III & IV	SIDE	PWB
POWER SUPPLY 610	1	III & IV	SIDE	PWB

- MODULE AND WIRING ACCESS COVERS
- MODULE INSERTION AND REMOVAL
- MODULE RESTRAINT
- MODULE IDENTIFICATION AND KEYING
- CLOSED AIR DISTRIBUTION SYSTEM USING COLD PLATE MODULE

46A/6-60

CHASSIS CONSTRUCTION

- EXTERNAL PANELS AND COVERS - CRUSHED HONEYCOMB SANDWICH, 0.10 THICK

  FORMED FROM: SKINS - 6061-T6 ALUMINUM SHEET, 0.010 THICK

  CORE - 5052 ALUMINUM HONEYCOMB, 0.125 CRUSHED TO 0.080

- CORNER JOINTS AND PANEL EDGES - 6063-T6 ALUMINUM EXTRUSIONS

  EPOXY BONDED TO PANELS

- AIR PLENUMS - 6061-T6 ALUMINUM SHEET SIDEWALLS (0.025 THICK)
  - HYDROFORMED END FITTINGS
  - 6063-T6 ALUMINUM EXTRUSIONS AT TOP AND BOTTOM
  - INTERNAL STIFFENERS OF PERFORATED ALUMINUM SHEET
  - BONDED WITH 0.005-INCH DIAMETER SILVER BEAD FILLED EPOXY
  - EPOXY BONDED

- MODULE GUIDES - POLYURETHANE MOLDED BUMPERS

- COVERS - ATTACHED WITH SPRING LOADED, CAPTIVE, SELF-LOCKING, QUAD LEAD, NON-STANDARD SCREWS

- BONDING MATERIAL - MODIFIED EPOXY RESIN EC 2214HD
  MMM-A-132, TYPE I, CLASS 3 ADHESIVE WITH 0.005 INCH DIAMETER SILVER BEAD ADDITIVE

46A/6-61

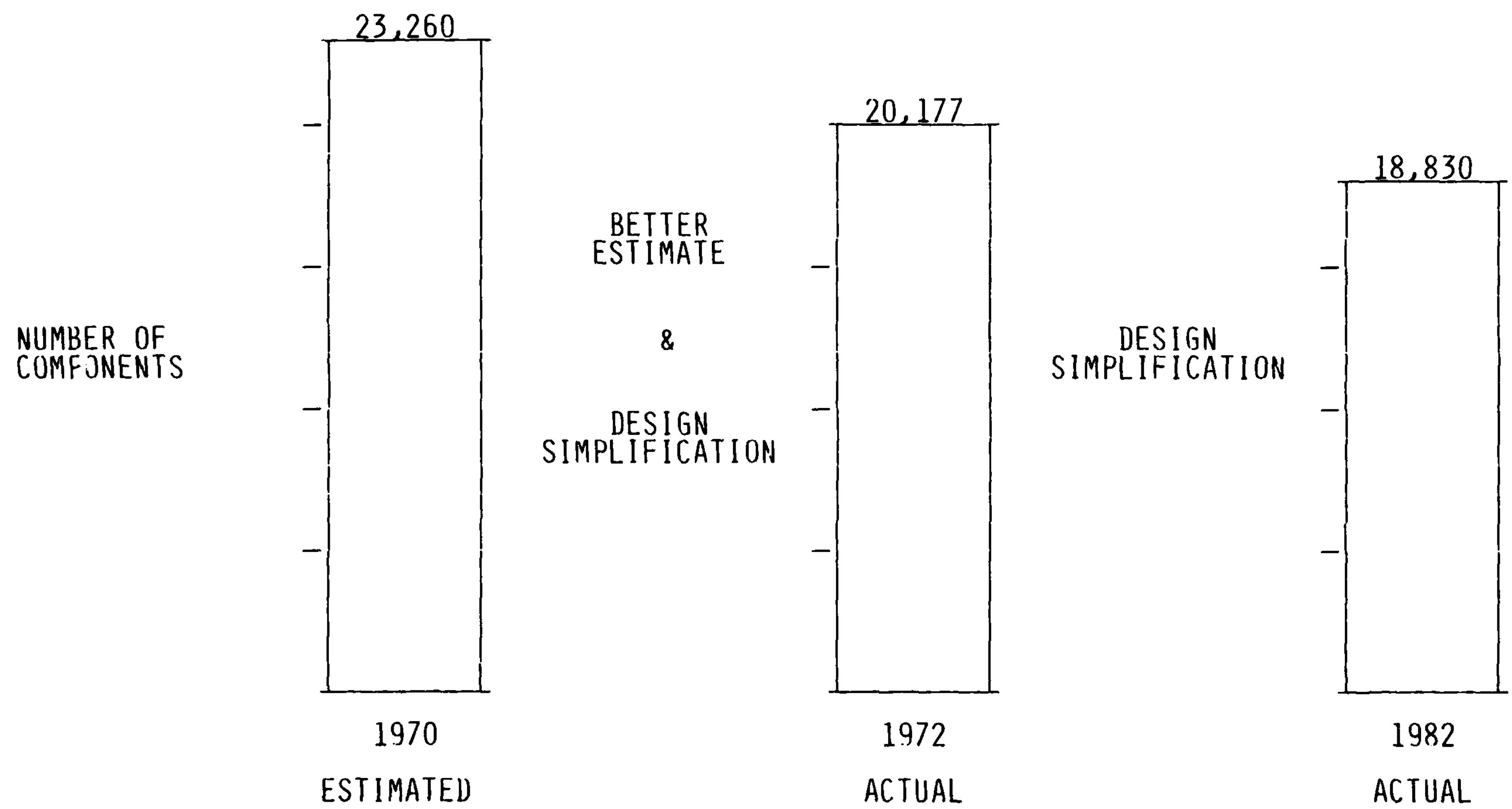
PREDICTIONS AND ANALYSES

1970 APG-63 RADAR RELIABILITY PREDICTION

UNIT	MTBF, HOURS
EXCITER - 001	625
TRANSMITTER - 011	510
RECEIVER - 022	1,020
ANTENNA - 031	613
ANALOG PROCESSOR - 039	474
DIGITAL PROCESSOR - 041	237
DATA PROCESSOR - 081	365
LOW VOLTAGE POWER SUPPLY - 610	1,695
RADAR CONTROL - 541	9,090
TARGET DESIGNATOR CONTROL - 560	11,100
MISCELLANEOUS UNITS (MICROWAVE COMPONENTS)	14,286
RADAR SET	62.5

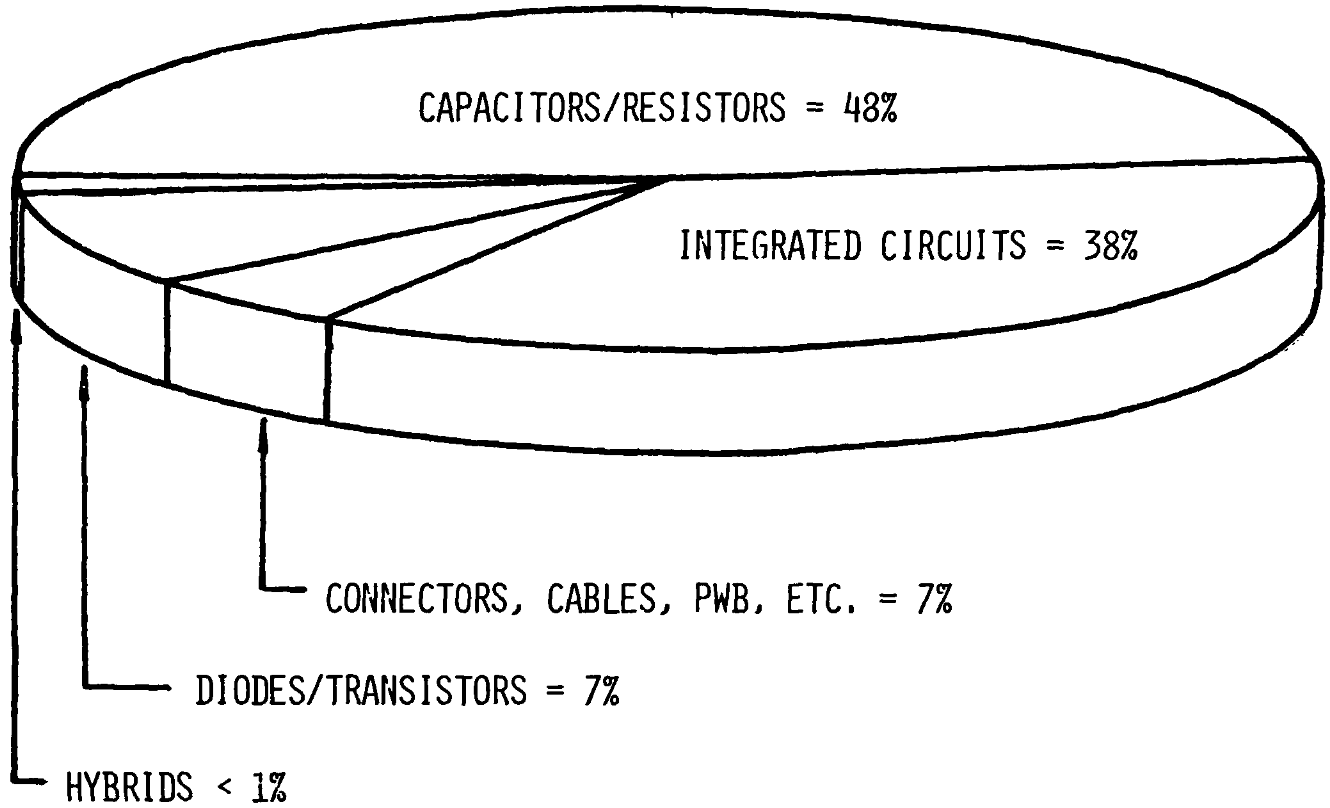
46A/6-23

19% FEWER RADAR COMPONENTS



46A/4

F-15 APG-63 COMPONENT PARTS



F-15 APG-63 COMPONENT PARTS

LRU	DIODES	TRANSISTORS	ICs	HYBRIDS	CAPACITORS	RESISTORS	MAGNETICS	CABLES	CONNECTORS	OTHERS	PWBs	TOTAL
001	48	29	5	10	156	217	110	35	49	17	15	691
011	222	55	88	5	235	597	23	7	46	46	12	1336
022	57	26	7	13	115	146	73	22	37	23	8	527
031	1	--	--	--	--	--	--	19	41	101	--	162
039	38	62	169	32	626	763	126	--	20	36	13	1885
042	47	26	4638	7	2015	283	18	--	14	101	45	7194
081	481	83	2110	7	1431	1754	68	--	5	13	50	6002
541	2	--	2	--	5	12	--	--	4	12	1	38
610	134	52	16	48	219	482	12	--	18	6	8	995
TOTAL	1030	333	7035	122	4802	4254	430	83	234	355	152	18830

46A/1-55

F-15 APG-63 PROGRAMMABLE SIGNAL PROCESSOR MTBD COMPARISON

AIMVAL/ACEVAL evaluation demonstrated that the tactical performance of the F-15 could be improved by incorporating certain changes to the radar fire control mechanization. The radar "software only" AIMVAL changes were incorporated into production aircraft in mid-1978. The remaining AIMVAL/ACEVAL improvements which required hardware changes (a raid assessment mode, a heading stabilized display, and a ground moving target inhibit capability), plus other improvements, are provided with the new radar programmable signal processor (PSP) delivered in production aircraft in May 1980. The PSP, which replaces the present hardwired signal processor, is an extremely fast computer which takes advantage of the structured nature of signal processing functions. Since its internal mode control and its signal processing are programmable, major changes in its operation can be made without hardware modification. The PSP will allow future planned improvements such as a track-while-scan mode by software only changes. The PSP represents application of advanced technology in radar signal processing.

The PSP 042 unit, which is a special high-speed programmable digital computer, replaces the original radar signal processor (RSP) 041 unit which is a hardwired signal processor. The PSP unit gives increased flexibility in the radar modes available. The radar data processor (RDP) 081 unit is modified to provide the increased memory required to store the PSP software programs. When the radar is initially turned on and during certain radar mode changes, the RDP unit loads the required program into the PSP memory.

Incorporation of this change caused mean-time-between-demand (MTBD) for the new PSP to increase 58 percent. MTBD for the radar data processor increased 78 percent.

F-15 APG-63 SIGNIFICANTLY CHANGED LRUs

	PRE PSP	POST PSP
RADAR SIG DIGITAL PROCESSOR	LRU 041 - 67 HOURS	LRU 042 - 115 HOURS
RADAR DATA PROCESSOR	LRU 081 - 56 HOURS	LRU 081 - 72 HOURS

FAULT ISOLATION

46A/6-24

BIT EVALUATION/DEMONSTRATION

- DURING THE BIT DEVELOPMENT, DESIGN REVIEWS WERE CONDUCTED PERIODICALLY TO MONITOR BIT DEVELOPMENT
- ANALYTICAL TECHNIQUES WERE DEVELOPED AND USED TO VERIFY BIT DESIGN REQUIREMENTS
- FAILURES DURING QUALIFICATION TEST WERE RECORDED AND EVALUATED TO VERIFY BIT REQUIREMENTS
- AS FIELD EXPERIENCE WAS ACQUIRED BIT SOFTWARE ROUTINES WERE REVISED TO CORRECT IDENTIFIED PROBLEMS

46A/3-5

LRU REPLACEMENT AT AIRCRAFT WITHOUT
A NEED FOR LRU ADJUSTMENT

THE ABOVE REQUIREMENT WAS MET BY:

- SYSTEM CALIBRATION VIA BIT FOR
  - VCO FREQUENCY - ELIMINATES A NEED FOR 180-DAY CRYSTAL ADJUSTMENT IN THE EXCITER
  - PHASE AND GAIN CALIBRATION - ELIMINATES THE NEED FOR ANTENNA HARMONIZATION
  - RANGE DELAY CALIBRATION - CORRECTS FOR VARIATIONS IN GTWT TUBE DELAYS FROM LRU TO LRU

TRADE-OFF STUDY RESULTS

FLIGHT-LINE AGE INITIALLY PROPOSED

- MEMORY LOADER VERIFIER TO LOAD BIT TEST SOFTWARE
- INTEGRATED DYNAMIC TESTER

TRADE-OFF STUDY WAS CONDUCTED AND CONCLUDED:

- MEMORY LOADER VERIFIER WAS NOT REQUIRED IF:
    - MEMORY IN THE RDP WAS INCREASED BY 4K WORDS FOR ON-BOARD BIT TESTING
- INTEGRATED DYNAMIC TESTER WAS NOT OPTIMUM:
    - ONLY A 2% INCREASE IN F_D, F_I DID NOT WARRANT THE EXPENSE OF AN IDT. (SEE REPORT NO. 01-025F-A DATED 1 JULY 1971)

SYSTEM DESIGN APPROACH FOR BIT

- END-TO-END TESTING WAS CHOSEN TO MINIMIZE HARDWARE PENALTY YET MAXIMIZE TEST BENEFITS
  - TRANSMITTER OSCILLATOR USED AS A TEST SOURCE
  - SYSTEM VCO USED TO PROVIDE DOPPLER SHIFT
  - SIGNAL PROCESSOR USED AS A TEST EVALUATOR
- FAULT MATRIX OF TEST RESULTS PROVIDES FAULT ISOLATION DATA BASE
  - 12 WORDS BY 12 BITS PROVIDE STORAGE FOR ALL BIT TEST RESULTS
  - MATRIX IS AVAILABLE AFTER FLIGHT VIA PROTECTED MEMORY
- SYSTEM BIT DESIGN PROVIDES
  - CONTINUOUS MONITORING END-TO-END FOR SELECTED MODE
  - MANUALLY INITIATED TESTING BOTH AIRBORNE AND ON THE GROUND

46A/6-67

F-15 BIT DESIGN APPROACH

THE FOLLOWING APPROACH WAS TAKEN:

- A SYSTEM TEST APPROACH MINIMIZED COMPLEXITY
- SIMPLE INTERFACES WERE USED
- SOFTWARE WAS USED EXTENSIVELY TO PROVIDE FLEXIBILITY
- TEST AND EVALUATION WAS MADE CONCURRENTLY WITH SYSTEM EVALUATION PHASES
- A ONE-MAN AUTOMATIC HANDS-OFF DESIGN WAS NEEDED DUE TO THE FIGHTER CONCEPT
- BIT WAS MATURED BY DESIGN CHANGES DICTATED BY FIELD REPORT DATA. (TOP-10 PROBLEMS WERE WORKED ON A PRIORITY BASIS)

46A/6-68

BIT TEST AND EVALUATION

BIT VERIFICATION WAS MADE AS FOLLOWS:

- MATHEMATICAL MODEL EVALUATION - (MONTE CARLO METHOD)
- STANDARD CONDITIONS - FAULT INSERTION AND DETECTION
- ENVIRONMENTAL QUALIFICATION TESTING - BIT DATA WAS COLLECTED AT ALL STAGES AND EVALUATED
- SYSTEM RELIABILITY AND QUALIFICATION TESTING - EACH 60 SETS, BIT IS THE PRIMARY TEST METHOD USED IN THIS TEST
- FLIGHT TESTING AT EDWARDS AFB
- FACTORY BURN-IN OF SYSTEMS - BIT IS THE ONLY TEST USED
- AIMVAL/ACEVAL DEMONSTRATIONS AT NELLIS AFB
- FIELD RESULTS AT LUKE AFB, LANGLEY AFB, AND HOLLOMAN AFB DICTATED DESIGN CHANGES

46A/6-9

DIGITAL MODULE SIMULATION AND TEST

APG-63

- DIGISAT (DIGITAL SIMULATION AND TEST) REPLACED SATGEN IN MID-70s
- MORE CAPABILITY THAN SATGEN:
  - PROCESS MORE TEST PATTERNS FASTER
  - SIMULATE LARGER MODULES
  - BETTER STATUS REPORTING: UNDETECTED FAULTS LIST, INTERNAL STATES, TOGGLE COUNT, RACE CONDITIONS
- DTS 70, TESTAID/FASTRACE
  ATG/TEST SYSTEM DEVELOPED BY HEWLETT PACKARD
- USED AT HUGHES AND DEPOT FOR TESTING PSP DIGITAL MODULES
- HAS A "GUIDED PROBE" FOR ISOLATION TO A SINGLE COMPONENT
- FIELD (DEPOT) TESTS ARE KEEPING PACE WITH FACTORY UPGRADES
- PRESENT FAULT DETECTION % RANGES FROM 89.7% TO 99.9%

  REQUIREMENT: 85% MINIMUM FOR ANY ONE MODULE AND
  90% AVERAGE OVER ALL MODULES

46A/6-69

DIGITAL MODULE SIMULATION AND TEST

APG-63

- APG-63 RADAR WAS ONE OF THE FIRST SYSTEMS TO USE AUTOMATIC TEST GENERATION (ATG) FOR TEST OF COMPLEX DIGITAL MODULES (UP TO 3400 CIRCUIT MODES)
- SATGEN (SEQUENTIAL AUTOMATIC TEST GENERATION)-- DEVELOPED DIGITAL MODULE SIMULATOR/TEST SYSTEMS
    - ON-LINE EARLY 70s
    - USED FOR TESTING 081 AND 041 MODULES IN FACTORY AND DEPOT
    - PROVIDED FAULT DETECTION PERCENTAGE ESTIMATE AND AUTOMATIC FAULT ISOLATION WITH SEMI-AUTOMATIC BACK-UP
    - USES SAME DESIGN DATA BASE AS OTHER CAD/CAM OPERATORS

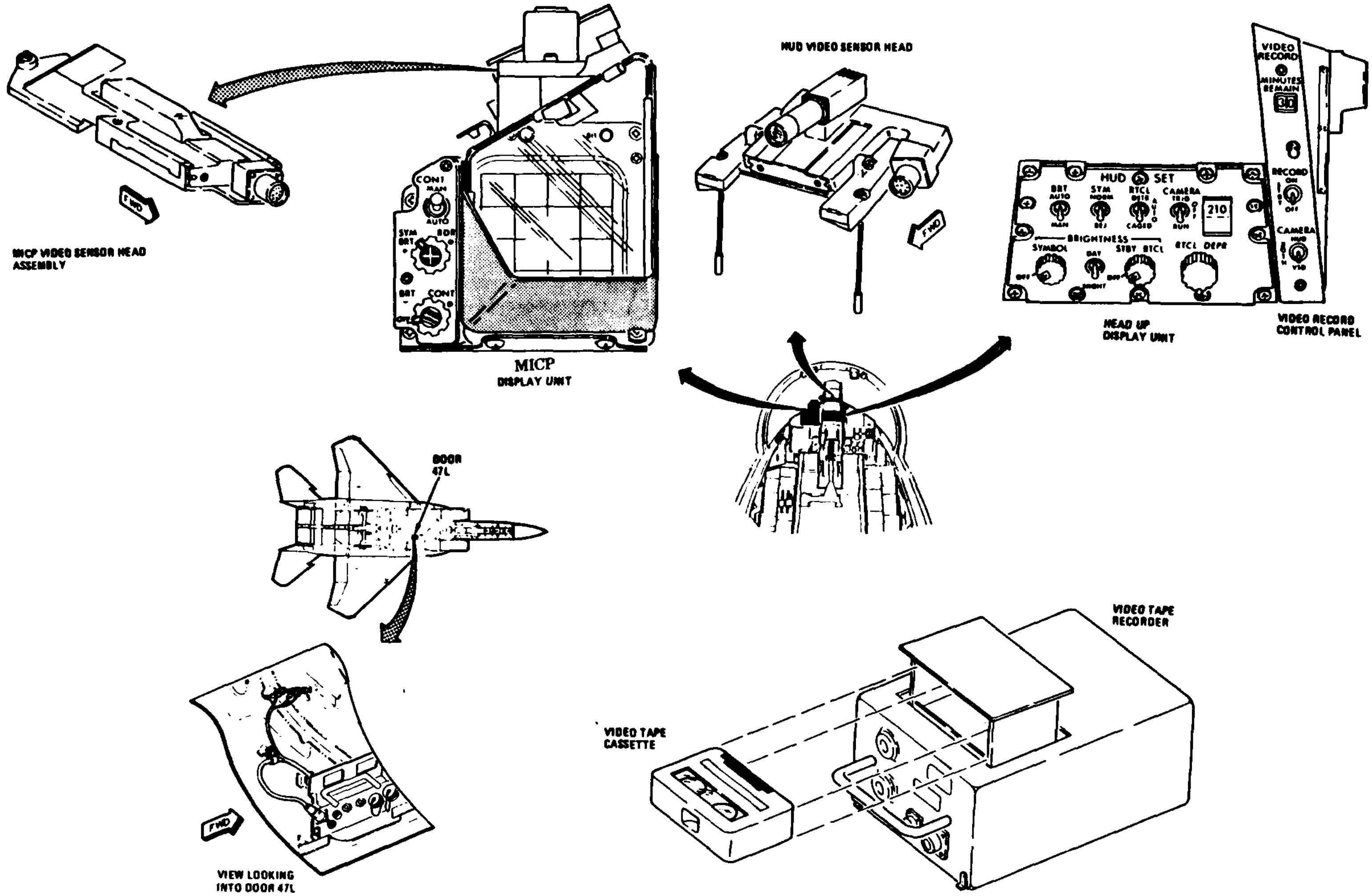
46A/6-70

FAULT ISOLATION USING VIDEO TAPE RECORDING SYSTEM (VTRS)

The VTRS uses two video cockpit TV sensor assemblies to get an inflight video tape recording of the multiple indicator control panel (MICP) display and the HUD presentation. Voice communications to and from the pilot are recorded on the audio track to aid correlation of inflight occurrences. One of the cockpit TV sensor video outputs is selected by the VIDEO RECORD control panel. It is routed through the video switching panel and recorded by the video tape recorder. The presentation of the recorded display along with the audio can be obtained when the video tape cassette is played back on monitoring equipment.

The VTRS has been a tremendous aid in fault isolation for the Radar System. The video tape cassette is removed from the aircraft by the Crew Chief and is available for being displayed on a monitor for pilot debriefing. The pilot can show the de-briefing technician exactly what he saw on the MICP display during flight. The VTRS is especially useful for isolating faults that are of an intermittent nature.

VIDEO TAPE RECORDING SYSTEM (VTRS)



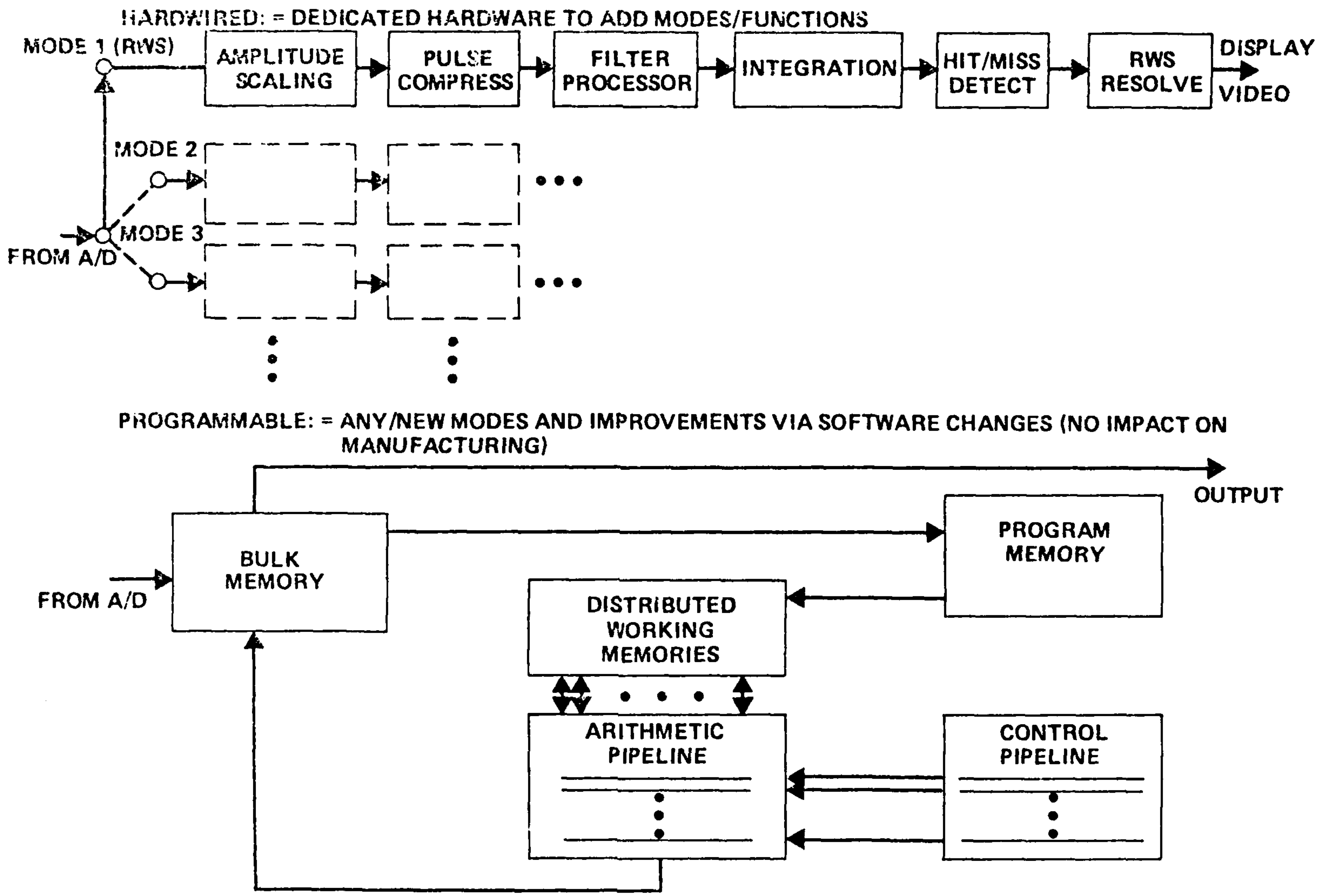
F-15 APG-63 PROGRAMMABILITY ALLOWS RECONFIGURATION FOR NEW MODES VIA SOFTWARE

Block diagrams are shown which compare the conventional hardwired and the programmable digital processor concepts. The functions shown in the hardwired diagram represent the air-to-air search mode as implemented in the present APG-63 radar digital processor (041) unit. Dedicated, specialized logic sections in the processor unit are devoted to each major function, and the incoming data flows serially as shown through these separate sections where the indicated operations are performed. In the programmable approach, the output of the A/D converter is fed directly into a temporary storage element, or bulk memory, from which it is retrieved at a data rate compatible with the PSP cycle time. The bulk memory also serves as a scan converter for the display and provides storage for the PSP programs and coefficients, which are read in from the radar data processor for the particular mode being exercised.

Instructions flow from bulk memory into the small, dedicated, fast program memory in blocks required for immediate use. These instructions cause data to flow into and out of small rapid access working memories which are distributed to allow multi-operand operations typically encountered in radar signal processor applications to be performed in a single clock cycle. The data being processed flows step by step through a very fast arithmetic section where iterative operations are performed. A pipeline effect is created which may be likened to a production assembly line, with instructions flowing down the control pipeline and being executed at various stages in the arithmetic pipeline. Each step is executed in one processor clock cycle, 140 nanoseconds. Thus, once the pipeline is filled, the fully processed data flows out at an execution rate equal to the cycle time, and this enormous throughput permits the processor to keep up with the continuous stream of data entering the radar receiver, much as the hardwired processor does with its special purpose, pipelined logic.

46B/6-2

PROGRAMMABILITY ALLOWS RECONFIGURATION FOR NEW MODES VIA SOFTWARE



THE EVOLUTION OF THE APG-63 RADAR

F-15 A & B MODELS

16K COMPUTER (MAGNETIC CORE MEMORY)

LONG RANGE SEARCH MODES
AUTO ACQUISITION MODES

ECCM
- AOJ
- HOJ
- 6 RF CHANNELS
- MED PRF VGS/RGS
- SNIFF

SINGLE TARGET TRACK

AIM 7F

AIM 7M (SINGLE TARGET)

24K COMPUTER (SOLID STATE MEMORY)

PLUS:

AIMVAL/ACEVAL MODES
- AUTO GUNS
- SPLIT S TRACKER

IMPROVED SUPERSEARCH

AMRAAM (SINGLE TARGET)

F-15 C & D MODELS

96K COMPUTER (SOLID STATE MEMORY)

PROGRAMMABLE SIGNAL PROCESSOR

PLUS:

RAM MODE

TWS

3/8 MED PRF

ECCM
- HIGH PRF VGS
- PASSIVE RANGING

AMRAAM (MULTI-TARGET)

DBS

ADVANCED APG-63 RADAR

NEW COMPUTER
NEW ANALOG SIGNAL CONVERTER

COMBINED RECEIVER/EXCITER

PLUS:

NCTR (STT AND TWS)
VECTOR SCAN MODE*
ECCM
- INCREASED RF BANDWIDTH
- FREQUENCY AGILITY
- RF, IF SENSORS AND IMAGE REJECTION
- *ADDED RDP MEMORY AND SPEED*

REDUCED MUTUAL INTERFERENCE
- INCREASED RF BANDWIDTH
- GUARD RECEIVER IN HIGH AND MED PRF
- REDUCED TRANSMITTED SPECTRUM

ADDED MODE CAPABILITY
- EXTENDED HIGH PRF VELOCITY COVERAGE
- GREATER SYSTEM DYNAMIC RANGE*
- ENHANCED TWS
- MEMORY AND SPEED GROWTH

IMPROVED MAINTAINABILITY
- EXTENSIVE BIT SOFTWARE
- ADDITIONAL TEST TARGETS
- EXTERNAL INTERACTION AND TEST

AIM-7M (DUAL TARGET)
AMRAAM GROWTH
MIL STD 1750A ARCHITECTURE
- JOVIAL HOL COMPATIBLE

* SMALL CROSS SECTION TARGET DETECTION CAPABILITY

PSP TAPE INCORPORATION

1980 — MAR APR MAY — — — OCT NOV DEC — — —

INITIAL PSP TAPE

- BASELINE MODES
- HEADING STABILIZED DISPLAY
- IMPROVED GMTI
- NEW MPRF PULSE MODE

1ST PSP UPDATE TAPE

- ALL CAPABILITIES IN INITIAL PSP TAPE
- NEW SUPERSEARCH MECHANIZATION
- DBS MAP
- ADDITIONAL GMTI

1981 — APR MAY — — — OCT NOV DEC — — —

2ND PSP UPDATE TAPE

- ALL CAPABILITIES IN 1st PSP UPDATE TAPE
- RAID ASSESSMENT MODE
- MUTUAL INTERFERENCE IMPROVEMENT

3rd PSP UPDATE TAPE

- ALL CAPABILITIES IN 2nd UPDATE TAPE
- RAM IMPROVEMENT FEATURES
- RAM - SPACE DESIGNATION
- SUPPRESS AOJs FROM MLC EFFECTS

GP23-0133-3

ACRONYMS

DBS ... Doppler Beam Sharpening

ECCM ... Electronic Counter-CounterMeasures

GMTI ... Ground Moving Target Inhibit

MPRF ... Medium Pulse Repetition Frequency

NCTR ... Non-Cooperative Target Recognition

RAM ... Raid Assessment Mode

TWS ... Track While Scan

All the software programs needed for the PSP to perform all the modes presently utilize 60K words of memory out of the 96K words of memory available in the Radar Data Processor.

F-15 RADAR MAINTAINABILITY VERIFICATION RESULTS

MAINTAINABILITY SPECIFICATION

PARAMETER	SPECIFICATION	VERIFICATION
MMTR	< 0.77 HRS	0.37 HRS
MTBMA	> 15 HRS	22 HRS

46A/1-62

VERIFICATION

METHOD	- Demonstration
LOCATION	- Hughes Aircraft
DATE	- November 1973-September 1974
PROCEDURE	- MDC Report G-117-Vendor/Subcontractor Maintainability Requirements Verification Standard

46B/1-45

F-15 RADAR MAINTAINABILITY

(PERFORMANCE VERSUS SPEC REQUIREMENTS)

PARAMETER	SPEC REQMT.	DEMONSTRATED PERFORMANCE	% EXCEEDING SPEC.
MMTR (O & I)	1.55 HRS		
MMTR (I) FAULT ISOLATION & VERIFICATION	.78 HRS		
MMTR (O & I) MAINTENANCE ACTIONS	.77 HRS	.365 HRS	47% BETTER THAN SPEC
MTBMA	15.0 HRS	22.29 HRS	48% BETTER THAN SPEC

46A/6-49

F-15 RADAR PROGRAM ELEMENTS

SPECIFICATIONS	RELIABILITY	MAINTAINABILITY
DESIGN	• GROWTH TO 60 HOURS • MODULE HEAT EXCHANGER	• MMTR/MTBMA CRITERIA • SELF-CONTAINED BIT--NO FLIGHT LINE AGE • SELF CALIBRATIONS--NO HARMONIZATION
PARTS	• PARTS CONTROL BOARD -- HIGH REL TYPE -- DERATING CRITERIA	• MODULAR CONSTRUCTION • ALL QUICK RELEASE DEVICES
SCREENING	• ALL ENCOMPASSING LEVEL CRITERIA -- PARTS -- MODULE CONDITIONING -- LRU AGING -- SYSTEM BURN-IN	• MMTR/MTBMA DEMONSTRATIONS
SYSTEM FEEDBACK	- 781B TESTING - MCAIR ICAP - MCAIR EAGLE WATCH - AF66-1 - MCAIR NORS ROOM	- NO FAILURES - 7 SUCCESSFUL TESTS - 148 PROBLEMS TRACKED - ON-SITE EARLY FIELD REPORTING

46A/6-50

MANUFACTURING

46/1-37

Environmental Stress Screening

A series of environmental stress screening tests were developed for F-15 radar. The screens were applied at all levels of manufacturing assembly: part, module, unit (LRU), and system. The purpose of the screens was to induce incipient or "infant mortality" failures prior to radar delivery. A mathematical model, termed "Look Ahead", was developed to optimize the screening levels and exposure. The results of previous program screening tests (principally the IRAM computer program) were used to determine the "strengths" to assign to each environmental stress. Existing facilities and capabilities were utilized as much as possible to reduce additional costs. The parameters of the various screening tests have been adjusted and refined due to cost effectiveness, evaluation of test data, and new techniques.

MANUFACTURING

- SCREENING TESTS

- ANALYTICAL MATH MODEL PROGRAM (LOOK AHEAD) DEVELOPED TO DETERMINE MOST COST-EFFECTIVE SCREENS AT PART/MODULE/LRU/SYSTEM LEVEL

- MODEL EVALUATED EFFECT OF:
  - INCOMING PART % DEFECTIVE REQUIREMENTS
  - TEMPERATURE CYCLING
  - TEMPERATURE EXTREMES
  - NUMBER OF CYCLES
  - DURATION OF EACH SCREEN
  - TEMPERATURE RATE OF CHANGE
  - VIBRATION (G LEVEL, TYPE, DURATION)
  - ON/OFF CYCLING
  - FAILURE DETECTABILITY

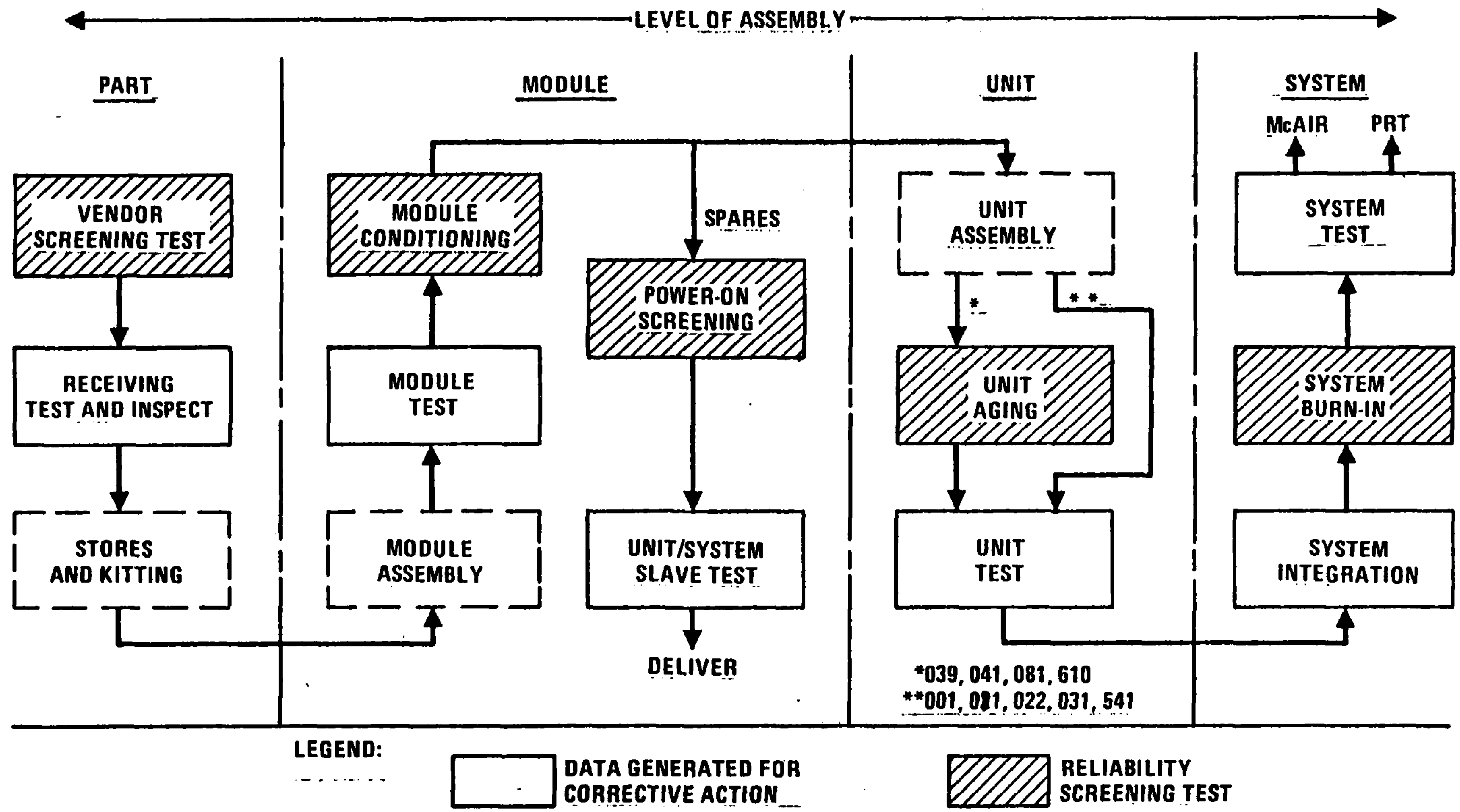
46/1-32

RADAR SET MANUFACTURING FLOW CHART

This chart shows the screening tests as they occur during the manufacturing assembly flow. Detailed parameters of each screening test are presented in subsequent charts. Unit aging is performed on four of the nine units receiving unit aging. These high-population units were chosen for additional screening since they contain 85 percent of the radar parts.

Modules that are sold as spare modules receive power-on-screening at the module level. Spare units receive aging (if applicable) and system level burn-in.

F-15 APG-63 RADAR SET MANUFACTURING FLOW CHART



F-15 APG-63 SCREENING PROGRAM--PARTS

PART SCREENING TESTS

APPLICABLE TO:	ELECTRONIC PARTS: ALL ICs AND HYBRIDS
CONDITIONS:	"B" LEVEL QUALITY SCREENS (MIL HI REL)
CONTROLLED BY:	GENERAL PART SPECS., INDIVIDUAL PART SPECS., AND AND PROCUREMENT DOCUMENTS

46A/6-71

EXAMPLE OF TYPICAL SUPPLIER PARTS SPECIFICATION REQUIREMENTS
100% SCREENING OF MONOLITHIC MICROCIRCUITS

Test/Inspection	Description of Test/Inspection	Duration	Temperature
Internal Visual Inspection (Precap)	MIL-STD-883, Notice 2, dated 20 November 1969, Method 2010.1, Condition B	X	X
High Temperature Storage	Non-operating Temperature Storage, MIL-STD-883, Method 1008, Condition C, Non-operational	24 Hours	150 ± 5°C (Ambient)
Temperature Cycling	Non-operating Temperature Cycling, MIL-STD-883, Method 1010, Condition C	10 Cycles	-65°C to +150°C (ambient)
Constant Acceleration	MIL-STD-883, Method 2001, Condition E, Y1 Axis, 30K g's	X	X
Seal Leak Test (Fine)	MIL-STD-883, Method 1014, Condition A or B, reject leak exceeding 1 x 10^{-8} atm/cc/second	X	X
Seal Leak Test (Gross)	MIL-STD-883, Method 1014, Condition C Or D		X
Pre Burn-in Electrical Parameters	Critical DC electrical parameters measured	X	X
Burn-in Test	MIL-STD-883, Method 1015, high temperature reverse bias and/or maximum power, depending on device type	168 Hours	125°C Minimum (Ambient)
Post Burn-in Electrical Parameters	Critical DC electrical parameters measured	X	X
External Visual	MIL-STD-883, Method 2009	X	X
Final Electrical Measurements	DC Characteristics and selected AC parameters	X	25°C (Ambient)

NOTE: An "X" under "Duration" or "Temperature" means that the indicated Test/Inspection is to be performed as defined under "Description of Test/Inspection".

SCREENING REQUIREMENTS

SCREEN TEST	TEMP CHANGE	RATE OF TEMP CHANGE	VIBRATION	CYCLE LENGTH	REQUIRED FOR COMPLETION	OPERATION WITH POWER
ASSY COND	$-60^{o}C$ TO $+95^{o}C$	$15^{o}C$/MIN	NA	30 MIN	23 HRS	NO
LRU AGING (039, 041, 042,081,610)	$-54^{o}C$ TO $+50^{o}C$	$20^{o}C$/MIN	NA	75 MIN (45 MIN ON/CYCLE)	40 HRS 1 FF CYCLE	ON - OFF
SYSTEM BURN-IN	$-65^{o}C$ TO $+71^{o}C$	$5^{o}C$/MIN	2.2G (AT NON-RESONANT FREQ 30 Hz) 30 MIN/CYCLE	195 MIN (110 MIN ON/CYCLE)	48 HRS 3 FF CYCLE	ON - OFF
SPARE ASSY POWER-ON	AIR COOLED $-55^{o}C$ TO $+45^{o}C$	$20^{o}C$/MIN	2.2G (AT NON-RESONANT FREQ 30 Hz) 30 MIN/CYCLE	150 MIN (95 MIN ON/CYCLE)	90 HRS FOR AGED UNITS MODULES 50 HRS FOR NON-AGED UNITS MODULES (011-0IL, 48 HRS)	ON - OFF
	LIQUID COOLED $-55^{o}C$ TO $+65^{o}C$	"	"	195 MIN (118 MIN ON/CYCLE)	EACH MODULE 1 FF BURN-IN CYCLE	

F-15 APG-63 SCREENING PROGRAM--ASSEMBLIES

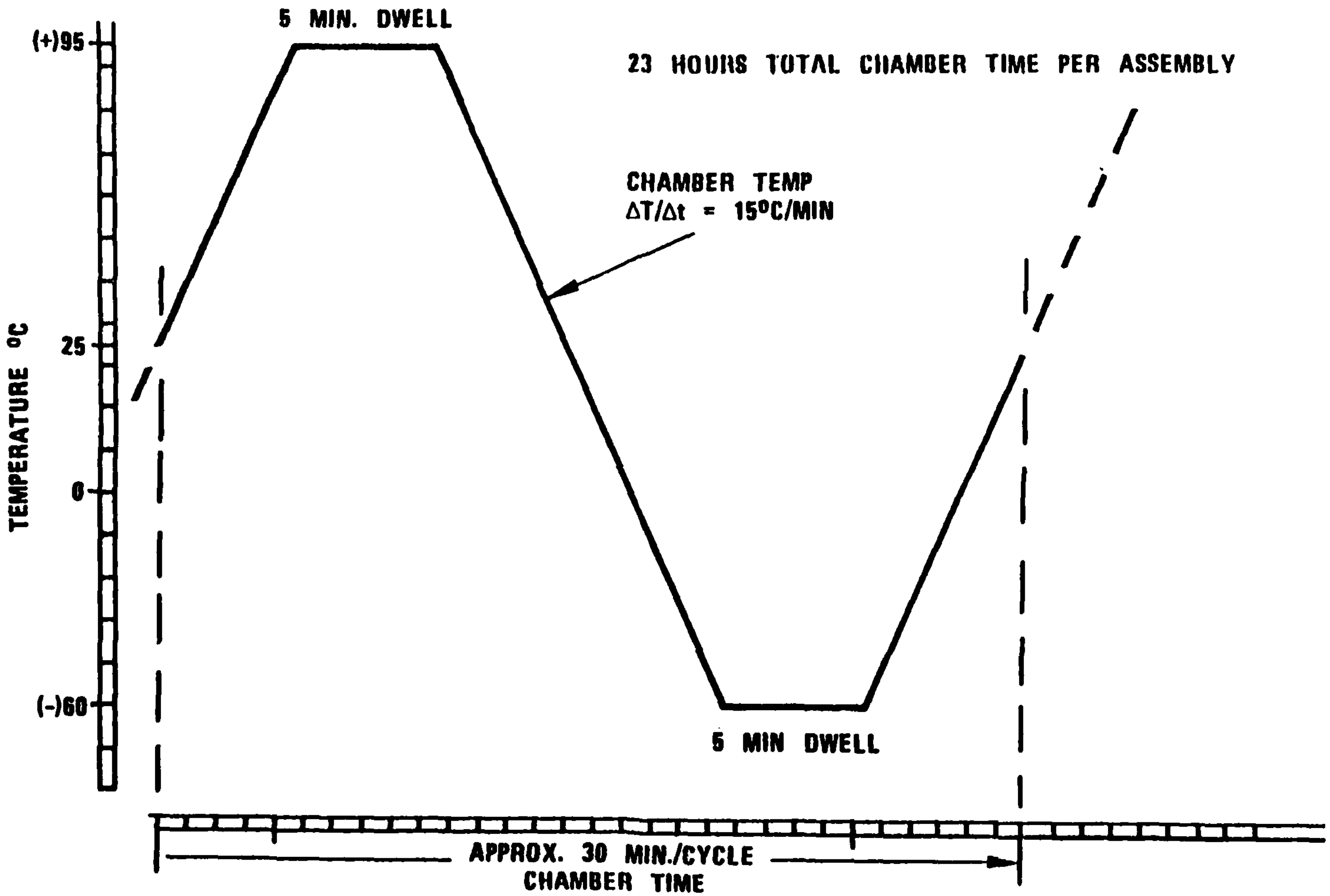
ASSEMBLY CONDITIONING (CARD OR MODULE)

APPLICABLE TO:	ALL ELECTRONIC ASSEMBLIES/SUBASSEMBLIES
CONDITIONS:	TEMPERATURE CYCLING, NON-OPERATING, BETWEEN -60°C AND +95°C, ΔT = 15°C PER MINUTE
DURATION:	46 CYCLES (23 HOURS)
CONTROLLED BY:	ASSEMBLY CONDITIONING SPECIFICATION, AC 31325-242

46A/6-25

F-15 APG-63 ASSEMBLY CONDITIONING

TEST CHAMBER PROFILE



10/78

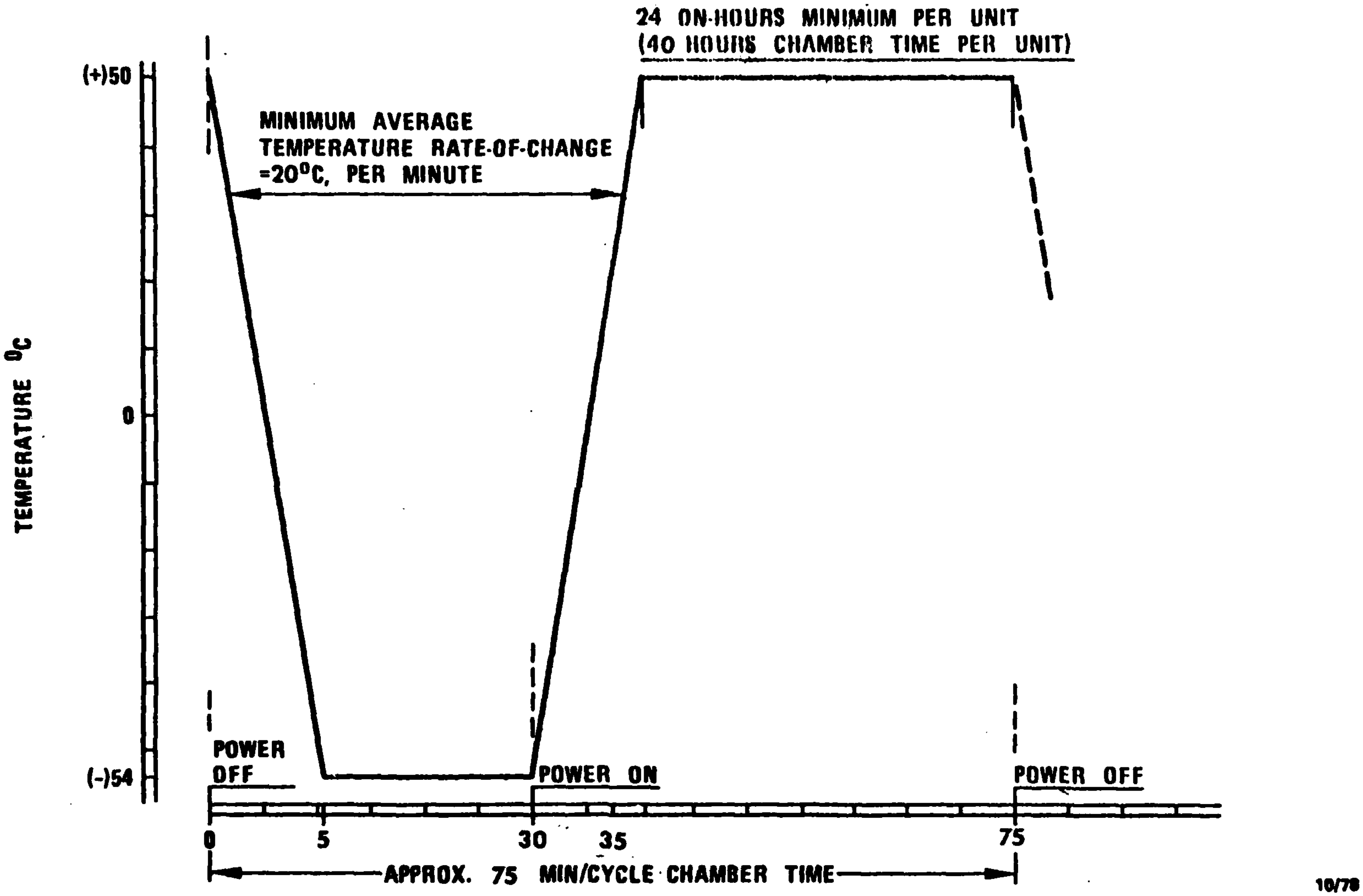
F-15 APG-63 RADAR SCREENING PROGRAM--UNITS

UNIT AGING

APPLICABLE TO:	ALL 039, 041, 081 AND 610 UNITS
CONDITIONS:	POWER-ON TESTS, TEMPERATURE CYCLING (-54°C TO +50°C) COOLING AIR
DURATION:	32 CYCLES (24 ON-HOURS, 40 CHAMBER HOURS)
CONTROLLED BY:	UNIT AGING SPECIFICATION, UA 31325-245

46A/6-72

UNIT AGING REQUIREMENTS--CHAMBER PROFILE



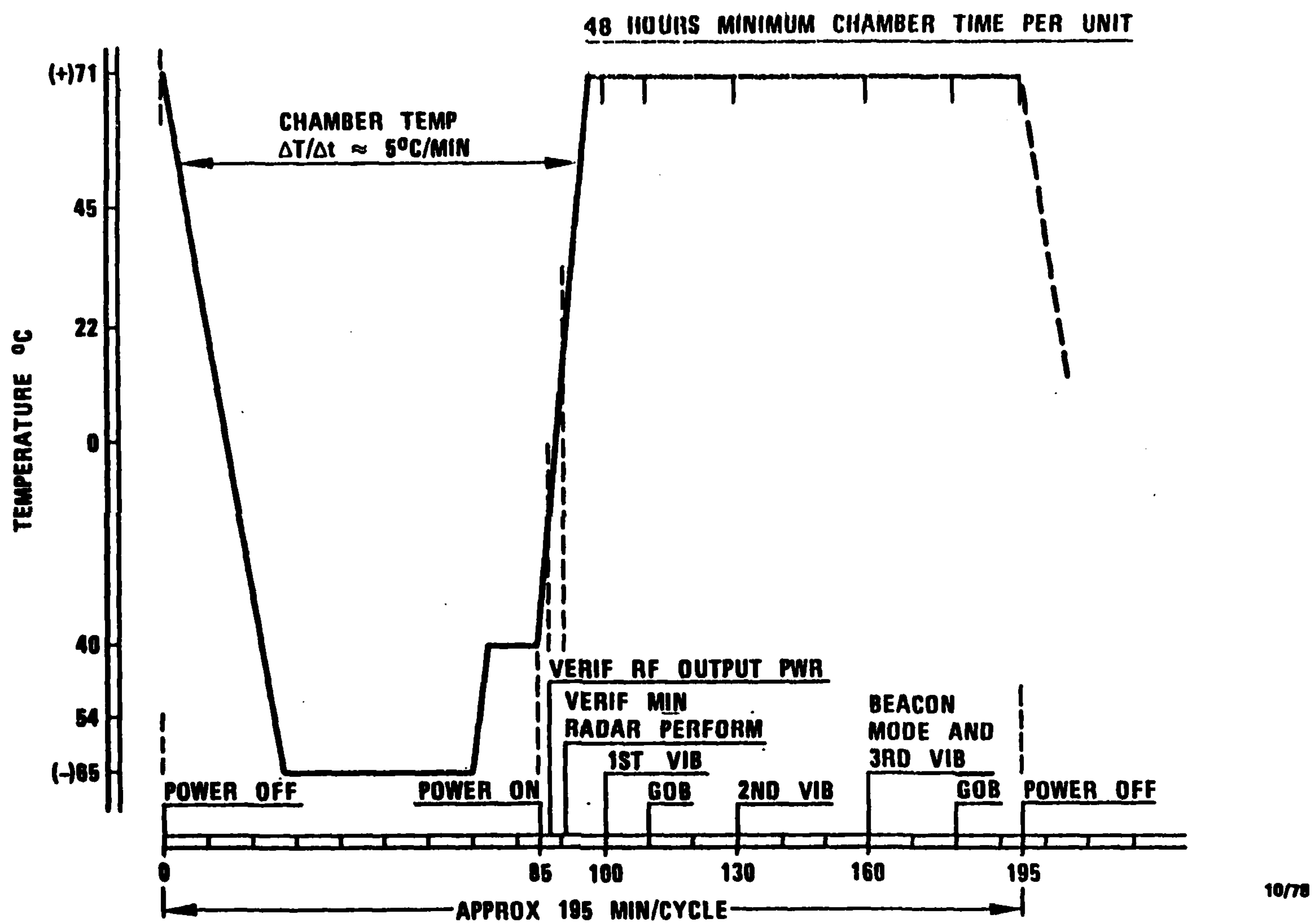
All F-15 units receive system burn-in. Each unit must accumulate a minimum of 48 chamber hours of burn-in and complete the final three cycles failure-free. Failure repair is usually accomplished by module (assembly) replacement. Each module (either original or replacement) in the unit must accumulate a minimum of 24 chamber hours.

SCREENING PROGRAM--SYSTEMS (RADAR SETS)

SYSTEM BURN-IN

APPLICABLE TO:	ALL F-15 RADAR LRUs (PRODUCTION AND SPARES)
CONDITIONS:	POWER-ON FUNCTIONAL TESTS, TEMPERATURE CYCLING (-65°C TO +71°C, CHAMBER AIR, SINUSOIDAL VIBRATION (2G's). MINIMUM REQUIREMENTS: 24 CHAMBER HOURS EACH ASSEMBLY; LAST THREE CYCLES FAILURE FREE EACH UNIT
DURATION:	15 CYCLES (48 CHAMBER HOURS)
CONTROLLED BY:	F-15 RADAR SET BURN-IN SPECIFICATION, BI 3173000-041

BURN-IN REQUIREMENTS--CHAMBER PROFILE



SPARES TESTING AND SCREENING

- ALL PRODUCTION SYSTEMS RECEIVED FULL BURN-IN
- NO INITIAL PROVISIONS FOR SPARES BURN-IN REQUIRED BY WRALC
- MAC/HAC RECOMMENDED SYSTEM EQUIVALENT BURN-IN FOR SPARE MODULES AND LRUs
- WARNER ROBBINS AND AFLC ADDED SPARES SCREENING REQUIREMENTS LATE 1976

C L E A R -- CLOSED LOOP EVALUATION AND REPORTING

FUNCTION--REPORT AND PROCESS

- FAILURE
- MAINTENANCE
- NONCONFORMANCE
- CORRECTIVE ACTION

46A/6-27

CLEAR

Early in the 1970s, MCAIR developed the CLEAR (Closed Loop Evaluation And Reporting) system to satisfy F-15 program needs for reliability, maintainability, and quality engineering information in addition to being compatible with the AFM 66-1 system. CLEAR integrated into one system what had previously been many separate MCAIR information gathering systems to provide non-conformance, malfunction, maintenance, and safety data. In addition to combining data sources, new multipurpose forms were designed and used to more efficiently input information into computer systems, thereby minimizing manual operations and providing expanded analysis and reporting capabilities. CLEAR is used during manufacturing, assembly, laboratory testing, supplier testing, flight testing and initial field operations, or where MCAIR is providing repair and support services. The system provides computerized outputs which are used to fulfill F-15 contract requirements for reliability, maintainability, and quality reporting.

The three major building blocks of CLEAR (reporting, input, and computer processing) have been steadily improved with time and adapted for use on the F/A-18 and currently the AV-8B.

CLEAR (CLOSED-LOOP-EVALUATION & REPORTING)

- MCAIR SYSTEM FOR COLLECTING NON-CONFORMANCE, MAINTENANCE AND FAILURE INFORMATION WITH COMPUTER REPORTING FOR ANALYSIS AND PRODUCT UPGRADING

- DEVELOPED FOR F-15 AND IMPROVED FOR F-18 USAGE

  ✓ SUPPLIER TESTS

  ✓ MCAIR BENCH & QUAL TESTS

  ✓ PILOT SQUAWKS

  ✓ ON/OFF AIRCRAFT REPAIRS

  ✓ SUPPORT OF CUSTOMER TESTS

46/1-28

C L E A R -- MCAIR FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION SYSTEM

- COMPATIBLE WITH CUSTOMER REPORTING SYSTEM
- IDENTIFY PROBLEMS
- ANALYZE PROBLEMS
- TAKE CORRECTIVE ACTION
- DETERMINE COMPLIANCE WITH R&M REQUIREMENTS
- PROVIDE FEEDBACK TO THE CUSTOMER

USE OF CLEAR FORMS DURING FLIGHT TESTING

The number of CLEAR forms that need to be completed and the information gathered is usually greater during flight testing than during manufacturing or laboratory operations. After a test flight is completed, the reporting cycle begins with the pilot filling out CLEAR form A to list any "squawks" against the airplane and to record flight times in addition to other pertinent information. After the form A and pilot debriefing is complete, a separate form B is prepared for each pilot squawk. This form is used to document all data concerning the on-aircraft (organizational level) repairs. If repairs can be made on aircraft without removing a unit for additional test, the form B is completed, stamped off, and routed to the data center to input to the CLEAR system.

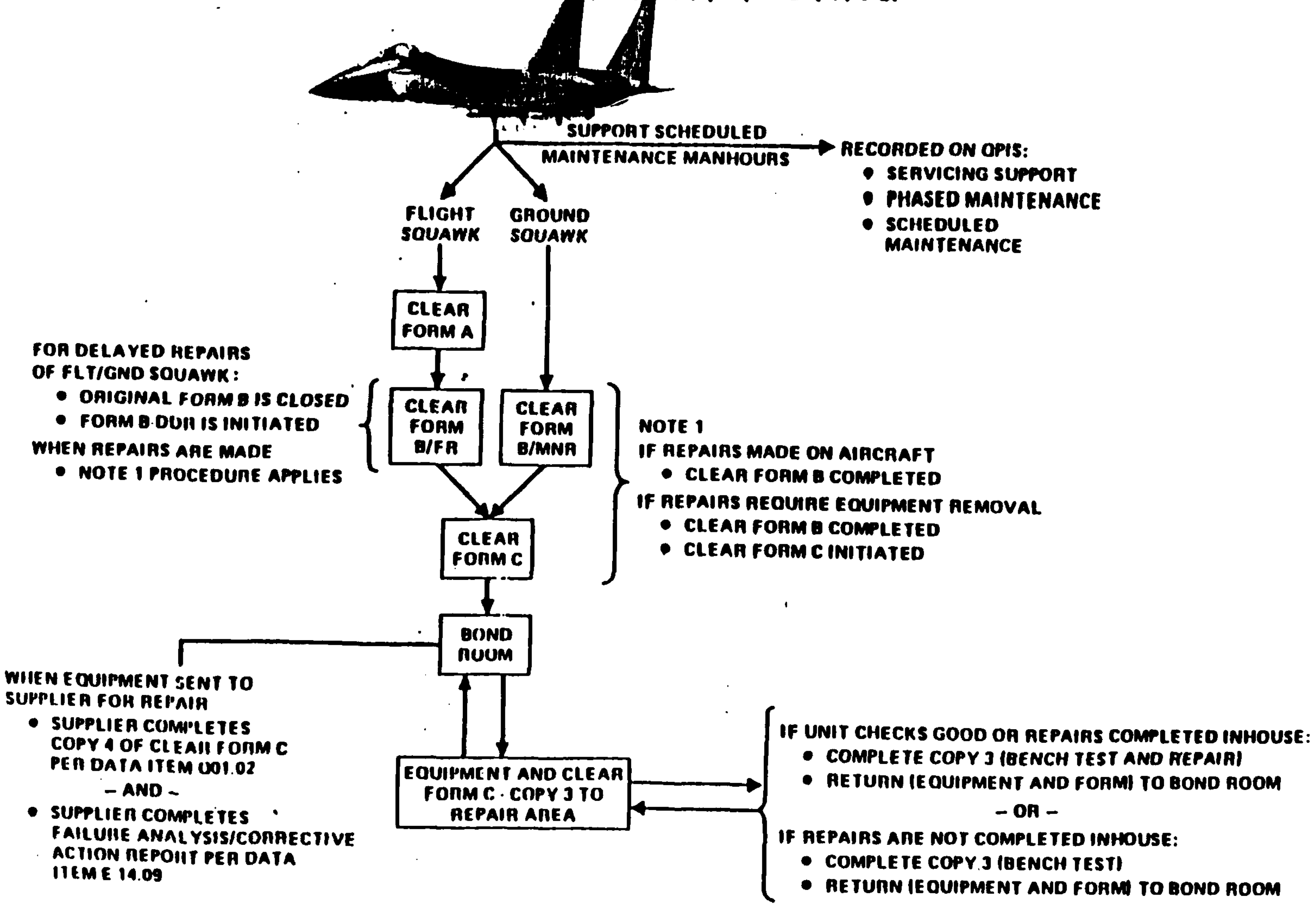
If it is necessary to remove a unit for test and/or repair, a form C is initiated to record the off-aircraft (intermediate level) test and repair data. This form is attached to the unit and taken to the bond room for disposition. Good units are returned to the aircraft or stores and defective units (or equipment) are returned to the supplier for repair. Following disposition, the Clear form C is completed and a copy routed to the data center to input to the CLEAR system.

This information is stored by CLEAR and, upon request, various computer outputs are provided to serve program analysis and product improvement needs.

46A/19-10

CLEAR

USE OF CLEAR FORMS DURING FLIGHT TESTING



HUGHES FAILURE REPORTING, ANALYSIS AND CORRECTIVE ACTION SYSTEM

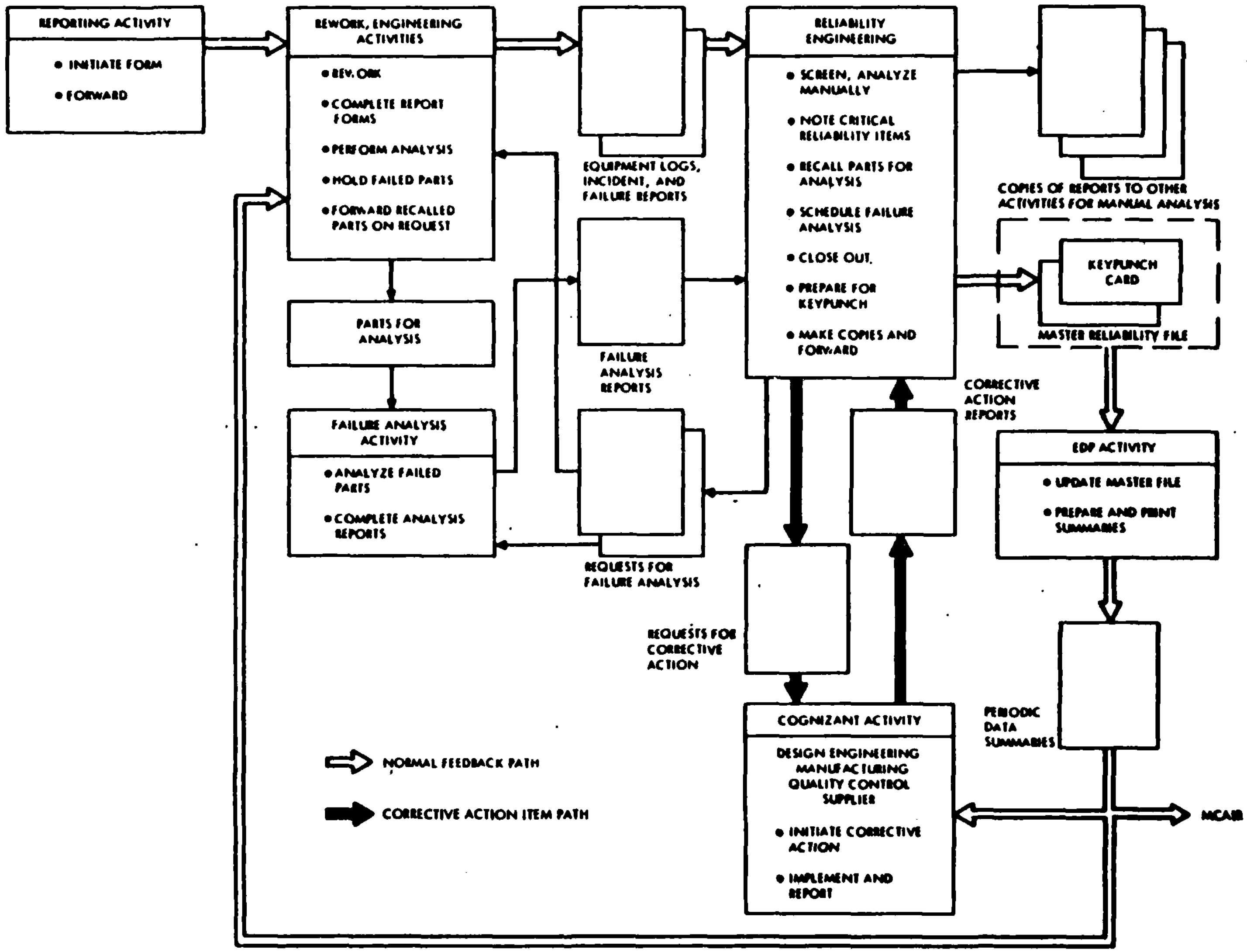
- HUGHES TROUBLE AND FAILURE REPORT (TFR)

- TFRs WRITTEN FOR ALL
  - UNIT AGING FAILURES
  - UNIT ACCEPTANCE TEST FAILURES
  - SYSTEM BURN-IN FAILURES
  - SYSTEM ACCEPTANCE TEST FAILURES

- ALL TFRs ANALYZED AND REPORTED TO CUSTOMER

46A/3-8

HUGHES TROUBLE AND FAILURE REPORT (TFR) SYSTEM



IID-27

Figure 5-5. Failure Reporting, Analysis, and Feedback Flow Diagram

MCAIR/SUPPLIER

INTEGRATED CORRECTIVE ACTION

PROGRAM

46A/6-29

INTEGRATED CORRECTIVE ACTION PROGRAM (ICAP)

- Intensifies the normal process of identifying and correcting problems on items that, by design have many components and will consequently generate numerous nonconformances that must be collectively analyzed to determine cause and corrective action. Items are initially selected on basis of complexity and/or probability of problems. Items may be added or deleted as required.

- Both MCAIR and the Supplier operate ICAP Committees comprised of Design Engineering, Reliability, Quality Engineering and other disciplines as required.

- Committees meet periodically to review all nonconformance and repair data, identify patterns and trends, investigate potential problems and identify and report problems requiring corrective action. Follow-up is conducted to ensure corrective action is effective.

- Data is exchanged between Committees following each meeting. As MCAIR and Supplier use the same nonconformance reporting form, the CLEAR (Closed Loop Evaluation and Reporting), overall review task is greatly simplified.

- A monthly ICAP Report is issued by MCAIR that provides a status of the problem and resulting corrective actions. This report is disseminated to MCAIR, Supplier and Customer management.

- This program assures the timely analysis and disposition of all nonconformance and repair data, provides for the earliest possible identification, reporting and correction of problems and distributes a current "Master List" of problems status and corrective actions.

FEATURES OF ICAP

- IT IS A MORE EFFICIENT METHOD OF DISPOSITIONING NONCONFORMANCES
- IT ASSURES COORDINATION OF THE DATA NEEDED FOR DISPOSITION,
- ESPECIALLY, WHERE TRENDS ARE THE NORMAL INDICATION OF PROBLEMS
- IT PREVENTS REDUNDANT DATA LOGGING, TRACKING, PROBLEM REPORTING/RESPONDING
- IT REDUCES COSTS - HELPS PREVENT PROBLEMS, REDUCING REWORK/REPAIR/RETROFIT, ETC.

ICAP COMMITTEE MEMBERS

- SUBSYSTEM MANAGER
- QUALITY ENGINEERING
- DESIGN ENGINEERING
- RELIABILITY ENGINEERING
- LOCAL HUGHES REPRESENTATIVE

46A/6-30

ICAP COMMITTEE PROCEDURE

- REVIEW ALL NONCONFORMANCE AND REPAIR DATA
- IDENTIFY PATTERNS AND TRENDS
- INVESTIGATE POSSIBLE PROBLEMS
- IDENTIFY AND REPORT PROBLEMS REQUIRING CORRECTIVE ACTION
- FOLLOW UP AND DETERMINE THAT CORRECTIVE ACTION IS TAKEN

ICAP PROBLEM REPORTING STATUS

- ICAP PROBLEMS REPORTED 148
- ICAP PROBLEMS CLOSED 142
- ICAP PROBLEMS OPEN 6

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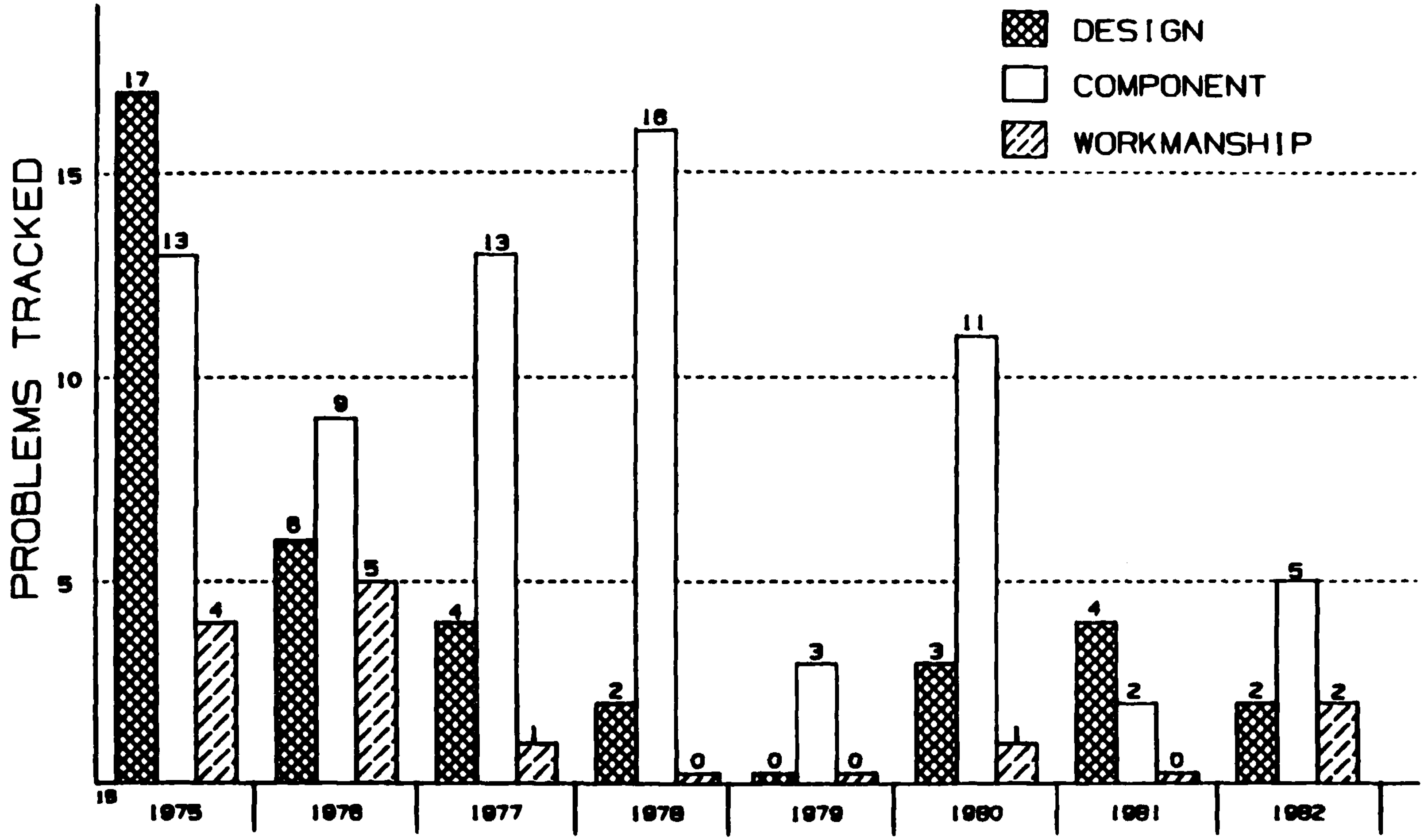
ICAP PROBLEM CATEGORIES

Category	QTY	%
Design - Problem reported was resolved by a circuit change (electrical), a mechanical change, or a revision to the requirement.	38	26
Component - A failure trend of a part not caused by application or circuit design. No attempt was made to identify part failures attributable to the design of the part itself.	72	48
Workmanship - A condition attributed to an error resulting during assembly (the equipment was not put together per the design).	13	9
Test Requirements - Revision to a test procedure or a change in the test equipment.	13	9
Miscellaneous - Problems which could not be placed in any of the previous categories, e.g., seven were closed as "no action required" since the investigation did not disclose a cause and the trend eventually subsided (possibly lot related).	12	8
TOTAL	148	100

The above breakdown is through 1982

MCAIR ICAP HISTORY



F-15 ICAP

- DESIGN PROBLEMS ELIMINATED EARLY IN THE PROGRAM
- COMPONENT PROBLEMS BECOME DOMINANT AS PRODUCTION CONTINUES
  - CONTINUOUS GUARDS REQUIRED ON SUPPLIER PARTS
- AGGRESSIVE, CONTINUOUS IN-PLACE CORRECTIVE ACTION SYSTEM MANDATORY

46A/3-2

SUMMARY

- PROVIDES FOR TIMELY ANALYSIS AND DISPOSITION OF ALL NONCONFORMANCE AND REPAIR DATA
- PROVIDES FOR EARLY IDENTIFICATION, REPORTING AND CORRECTION OF PROBLEMS
- DISTRIBUTES A CURRENT "MASTER LIST" AND STATUS OF PROBLEMS AND CORRECTIVE ACTIONS

TEST AND EVALUATION

EARLY RADAR OPERATING TIME EXPERIENCE

Most of the radar LRUs had elapsed time indicators (ETIs) and periodic readings were made throughout the development program to evaluate reliability and life. These operating time records were also used to correlate laboratory data and aircraft flight test data as a basis for predicting subsequent operational results and logistic support requirements. Much of the formal demonstration testing consisted of relatively short periods of operation, intermixed with facility and instrumentation check out, troubleshooting, modification verification, etc.

EARLY RADAR OPERATING TIME EXPERIENCE

YEAR	TIME		OPERATING TIME
1970	WB-66-Fly-off		521
1972/73	MCAIR Laboratory		2558
1972/74	Qualification Tests		>2200
1972/74	Category I Flight Tests		1943
1974	Reliability Qualification Tests		1160
1974/75	Category II Flight Tests		1716
		Total	>10,098

F-15 APG-63 RELIABILITY TESTS

COMPLETION DATE	TEST	RELEVANT OPERATING HOURS	RELEVANT FAILURES	RESULT
1974	30-HOUR TEST	150	4	PASSED
1976	45-HOUR TEST	130	1	PASSED
1977	1ST 60-HOUR TEST	256	3	PASSED
1978	2ND 60-HOUR TEST	180	1	PASSED
1979	3RD 60-HOUR TEST	381	6	PASSED
1981	4TH 60-HOUR TEST	341	5	PASSED
1982	5TH 60-HOUR TEST	465	8	PASSED

46A/5

MAINTAINABILITY VERIFICATION TEST

Maintainability verification plan was approved by MCAIR in January 1971. The test was accomplished concurrently with the 30-hour Reliability Qualification Test. The 30-hour Reliability Qualification Test and Maintainability Verification Tests were completed using Radar Sets 11 and 13 during 1974.

F-15 PROGRAM SCHEDULE

TITLE: MAINTAINABILITY VERIFICATION TEST

WBS/SCHED NO

DATE

PAGE 1 OF 1

PREP BY Stevens

DEPT NO 501

LEGEND

SCHED ACTUAL

SCHEDULED EVENT

RESCHEDULED EVENT

TIME SPAN ACTION

PROGRESS ALONG - TIME SPAN

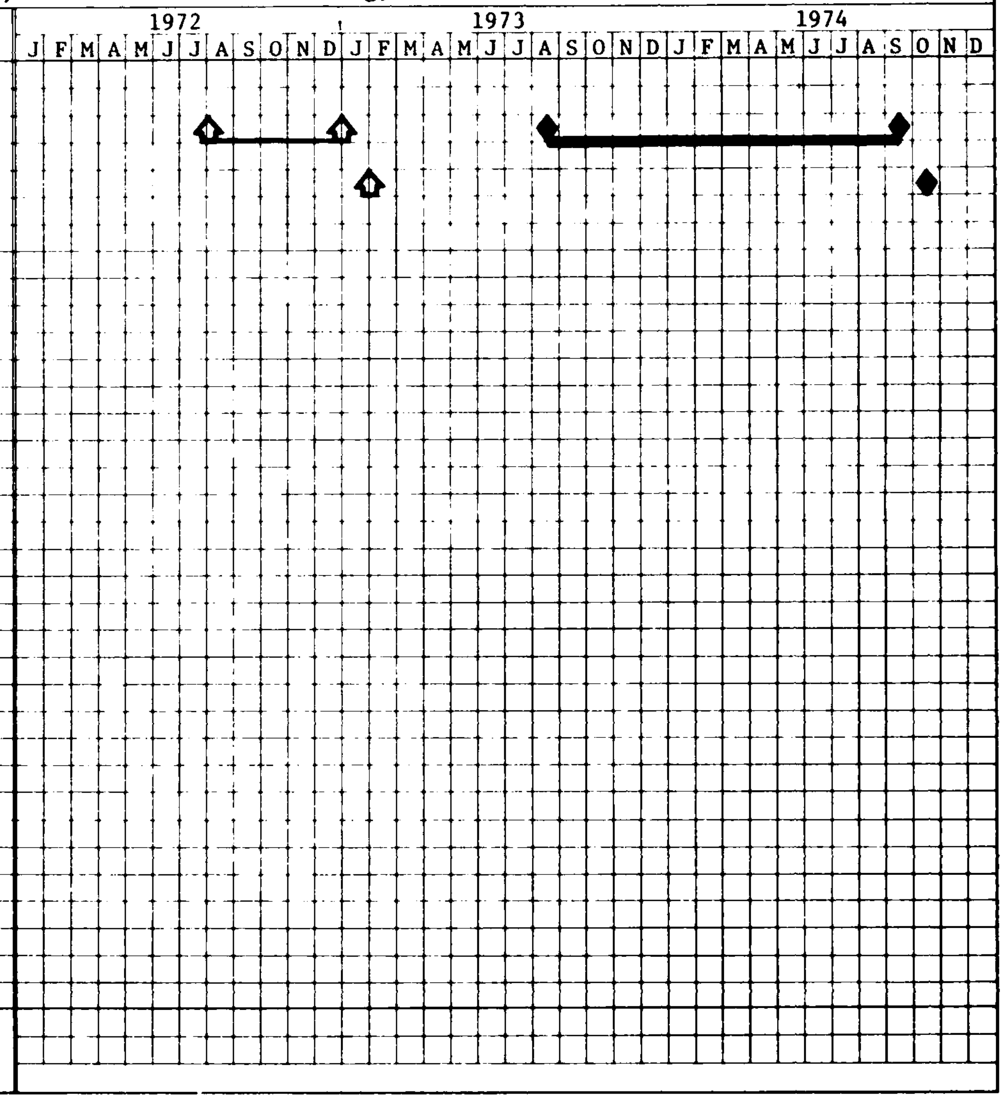
CONTINUOUS ACTION

DEMONSTRATION MILESTONE

REFERENCE: Data Items L-4 and L-5, Subcontractor Data Catalog, G392.

3 Maintainability Verification Test

5 Maintainability Verification Report



MCAIR F-15 SUPPLIER CHECKLIST

1. HAVE YOU VERIFIED THAT ANY DEVIATIONS AND WAIVERS ARE ACCEPTABLE? ____

2. HAVE YOU RECORDED THE TEST ARTICLE SERIAL NUMBERS INCLUDING THE LRU IDENTIFICATIONS AND THE ETI READINGS? ____

3. DOES THE TEST CHAMBER AND TEST EQUIPMENT HAVE CURRENT CALIBRATION STICKERS? ____

4. HAVE YOU PERSONALLY CHECKED TO SEE THAT THE CHAMBER TEMPERATURE MOVES AT AN AVERAGE RATE OF AT LEAST 5°C/MIN? ____

5. HAVE YOU PERSONALLY CHECKED TO SEE THAT THE CHAMBER REACHES THE REQUIRED TEMPERATURES (E.G., -54°C AND +71°C; HOLDS TO ±2°C)? ____

6. HAVE YOU PERSONALLY VERIFIED THAT OTHER TEST REQUIREMENTS ARE MET, INCLUDING COOLING AIR, VIBRATION, AND VOLTAGE LEVELS? ____

7. IS THE CHAMBER ADEQUATELY SEALED? ____

8. HAVE YOU PERSONALLY VERIFIED THE ACCURACY OF MANUAL PERFORMANCE READINGS TAKEN BY LAB TECHNICIANS? ____

9. ARE TEST LOGS/RECORDS AVAILABLE AND DO THEY INCLUDE WHAT HAPPENED TO EQUIPMENT DURING "DOWN TIME" OR "REPAIR"? ____

CONTINUED/.....

MCAIR F-15 SUPPLIER CHECK LIST (CONTINUED)

10. DOES THE TEST FACILITY OR EQUIPMENT HAVE AN ALARM OR LIGHT TO INDICATE A FAILURE WHEN THE TEST IS UNATTENDED AND IS IT "FAIL SAFE"? ____

11. DOES THE SUPPLIER TEST CONDUCTOR UNDERSTAND HIS OBLIGATION TO NOTIFY MCAIR OF ANY FAILURES BY TELECON/TWXs WITHIN 24 HOURS? ____

12. DOES THE SUPPLIER TEST CONDUCTOR UNDERSTAND THE NUMBER OF CYCLES/HOURS PERMITTED FOR INITIAL VERIFICATION AND REPAIR VERIFICATION? ____

13. DOES THE SUPPLIER TEST CONDUCTOR UNDERSTAND THAT UNAUTHORIZED REPAIRS MAY BE CLASSIFIED AS RELEVANT FAILURES? ____

14. IS THE SUPPLIER CONSCIENTIOUSLY CONDUCTING THE TESTS AND MINIMIZING DELAYS IN FAILURE REPAIR? ____

15. HAS THE AIR FORCE RELIABILITY ENGINEER BEEN NOTIFIED OF THE TEST START, INFORMED OF ANY DEVIATED CONDITIONS, AND DOES HE CONCUR IN THE FORMAL START OF RELIABILITY TESTING? ____

PLANNED vs ACTUAL RELIABILITY TEST

On the F-15 radar program, there were three discrete reliability tests: 30-hr test; 45-hr test; and 60-hr test. The 30-hr reliability qualification test (RQT), was started 14 months later than originally planned; the 45-hour production reliability test (PRT) test started 15 months later than originally planned; and the 60-hr PRT started approximately 16 months later than originally planned. Originally planned dates for the 30-hour test can be found in MCAIR, F-15 reliability program plan, report A048, dated 15 December, 1969. Planned dates for the 45- and 60-hour tests can be found in HACs F-15 reliability requirements & procedure manual, dated 1 November 19[illegible] (also included in management section of this report).

In the 1970 time period, some believed that environmental qualification tests should be completed, or nearly completed, and most of the fixes defined before reliability tests were started. The dilemma was one of starting reliability testing too soon and gathering information on early configurations versus later with more representative equipment. Early testing also carried additional risks of failing the test due to the lack of equipment maturity.

The schedule start date of September 1972 for the RQT was established by MCAIR ten months before selection of Hughes as the radar manufacturer and radar FSD go-ahead. It may be that this date was overly optimistic and did not properly allow for qualification test, facility, and other problems.

The first 30-hr MTBF ROT was started in November 1973, one year after Environmental Qualification Tests were initiated and four months before they were completed. Factors also contributing to the delay in the start date were reassignment of ROT assets and difficulties with test chamber facilities. During early attempts to start, test facilities were less reliable than the radar being tested.

Planned start dates for the production reliability tests (PRT) covering the 45-hr and 60-hr test were also delayed by 15 months or more. Reasons for this were incorporation of fixes that would permit attainment of the required MTBF and selecting test assets that would not compromise production deliveries. Many of the delays involved the solution to software problems which held up conduct of the test.

The planned growth of 30/45/60 hrs MTBF, was attained but at later calendar dates than originally scheduled. However, by June 1975 (end of Category II testing) the radar had passed the 30-hr and 45-hr reliability test and flight test results were indicating 46 hours MTBF. The 60-hr MTBF test was passed in January 1977. Four additional PRT have also passed the 60-hr test. As of December 1982, no APG-63 radar has failed to pass its required reliability test.

It is inherent in MIL-STD-781 demonstration testing, which places a premium on measured MTBFs, that prime contractors and subcontractors will be concerned with passing tests. Since there is a financial cost and a matter of reputation associated with failure, it follows that test delays tend to be the result since these do not involve incentives or substantial penalties.

APG-63 PLANNED VS. ACTUAL RELIABILITY TESTS

	PLANNED		ACTUAL	
	START	COMPLETE	START	COMPLETE
RQT (30-HR MTBF)	SEP 72	OCT 73	NOV 73	SEP 74
PRT (45-HR MTBF)	DEC 74	MAR 75	MAR 76	JUN 76
PRT (60-HR MTBF)	JUN 75	AUG 75	OCT 76	JAN 77

46A/1-66

GRIDDED TWT RELIABILITY QUALIFICATION TEST

DEMONSTRATION PARAMETER REQUIREMENTS

- θ_0 = 2000 HRS USING TWO PRE-PRODUCTION GTWTs
- TEST PLAN V OF MIL-STD-781B
- TEST LEVEL F OF MIL-STD-781B
- 12-HOUR CYCLE: 1 HOUR "OFF," 11 HOURS "ON"
- 10 MINUTES 2.2G 30-HZ VIBRATION PER ON HOUR
- TEST START AFTER 12/31/71 & COMPLETE BEFORE 10/1/72

RELIABILITY DEMONSTRATION TEST CONDUCT

- TEST START: 3/10/72
- TEST COMPLETION: 7/11/72

TEST TIME REQUIREMENTS

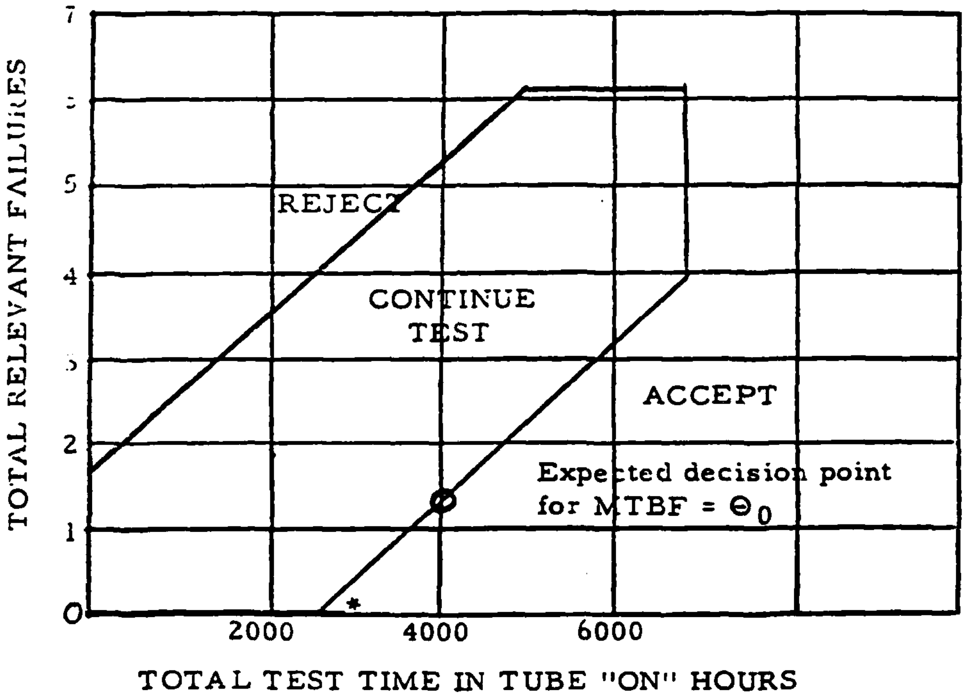
FOR

608H GTWT RELIABILITY QUALIFICATION TEST

Accept-Reject Criteria for: Test Plan V (MIL-STD-781B)

Decision Risks: 10%

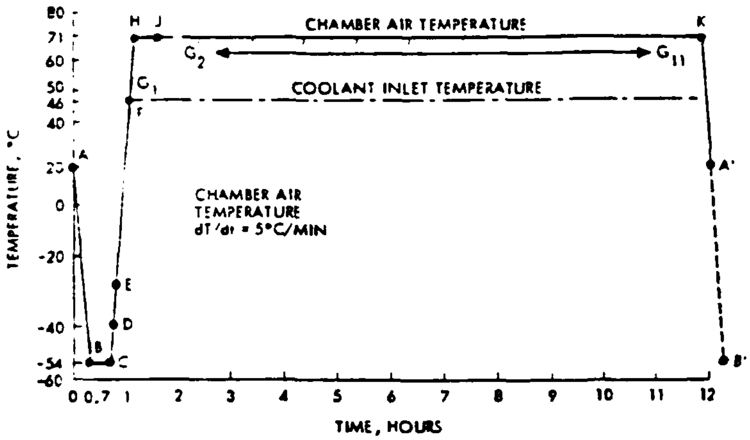
Discrimination Ratio: 3.0:1



Total Test Time vs. Number of Failures

No. of Failures	Reject (Equal or Less)	Accept (Equal or More)
0	N/A	2500
1	N/A	3600
2	380	4700
3	1480	5800
4	2580	6900
5	3680	6900
6	4780	6900
7	6900	N/A

*Time taken to successfully complete the test = 2567.4 ON hours.



POINT	LEGEND
A-B	GTWT OFF - DECREASING CHAMBER AND COOLANT TEMPERATURES, RECIRCULATE COOLANT
B-C	GTWT OFF - TUBE STABILIZATION AT LOW TEMPERATURE
C	GTWT GRID BIAS, SOLENOID, HEATER, AND ION PUMP VOLTAGE ON
C-D	INCREASING CHAMBER AND COOLANT TEMPERATURE
D	GTWT CATHODE AND COLLECTOR VOLTAGE ON, GRID DRIVE ON 10 SECONDS LATER
E	START MONITORING POWER OUT
D-F	INCREASING CHAMBER AND COOLANT TEMPERATURE
F	INLET COOLANT TEMPERATURE STABILIZATION AT 46°C
G_1-G_{11}	2.2g VIBRATION STARTED 15 MINUTES AFTER POINT D FOR 10 MINUTE PERIOD, AND THEREAFTER VIBRATION FOR 10 MINUTES OUT OF EVERY HOUR TO POINT G_{11}
F-H	INCREASING CHAMBER TEMPERATURE
H-J	GTWT STABILIZATION AT HIGH TEMPERATURE
J-K	GTWT OPERATION FOR PERIOD TO COMPLETE 12 HOUR CYCLE FROM POINT A TO A'
K-A'	GTWT OFF - DECREASING CHAMBER TEMPERATURE, RECIRCULATE COOLANT
A'-B'	START OF NEXT CYCLE (REPEAT OF A-B)

UNCLASSIFIED

GTWT Environmental Profile.

GRIDDED TWT RELIABILITY QUALIFICATION TEST (CONTINUED)

RESULTS

- 2 TUBES COMPLETED 2567.4 HOURS OF TESTING WITH
  - ✓ NO FAILURES
  - ✓ 214 COLD STARTS
  - ✓ 392 HRS VIBRATION

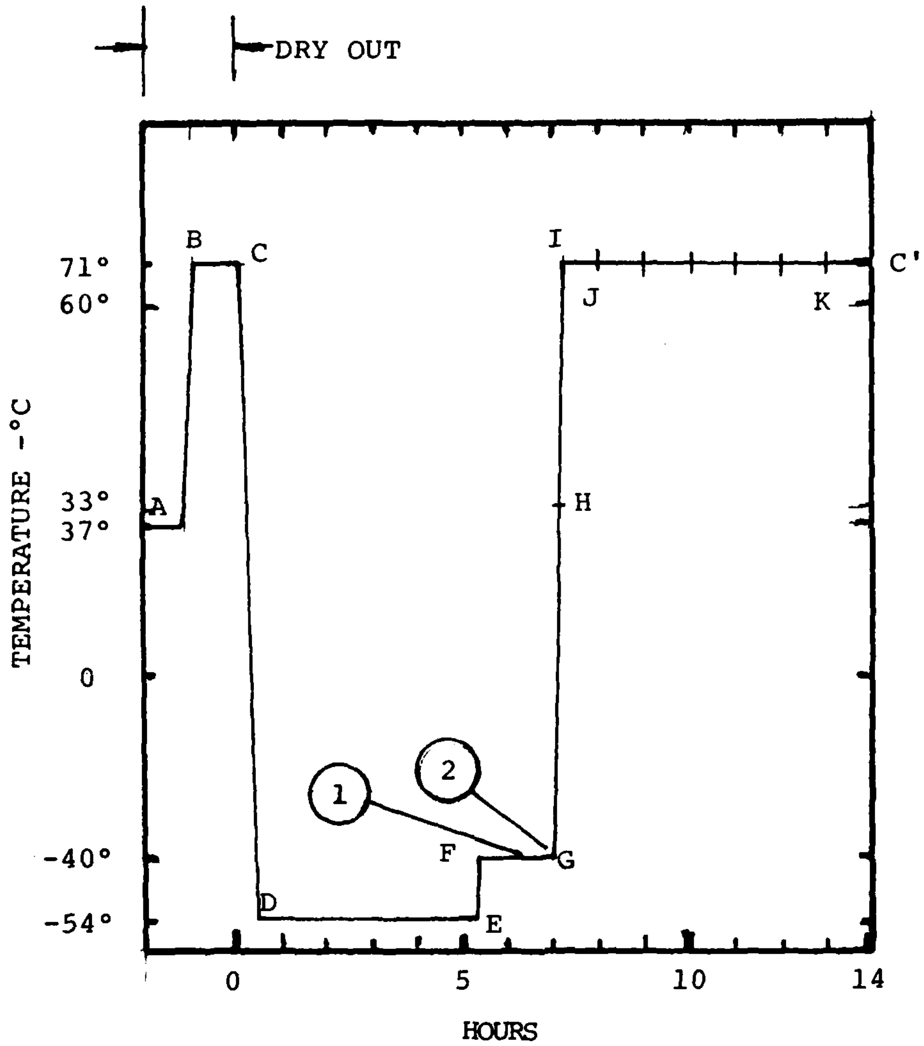
46A/3-7

F-15 RADAR RELIABILITY QUALIFICATION TEST

30-HOUR TEST

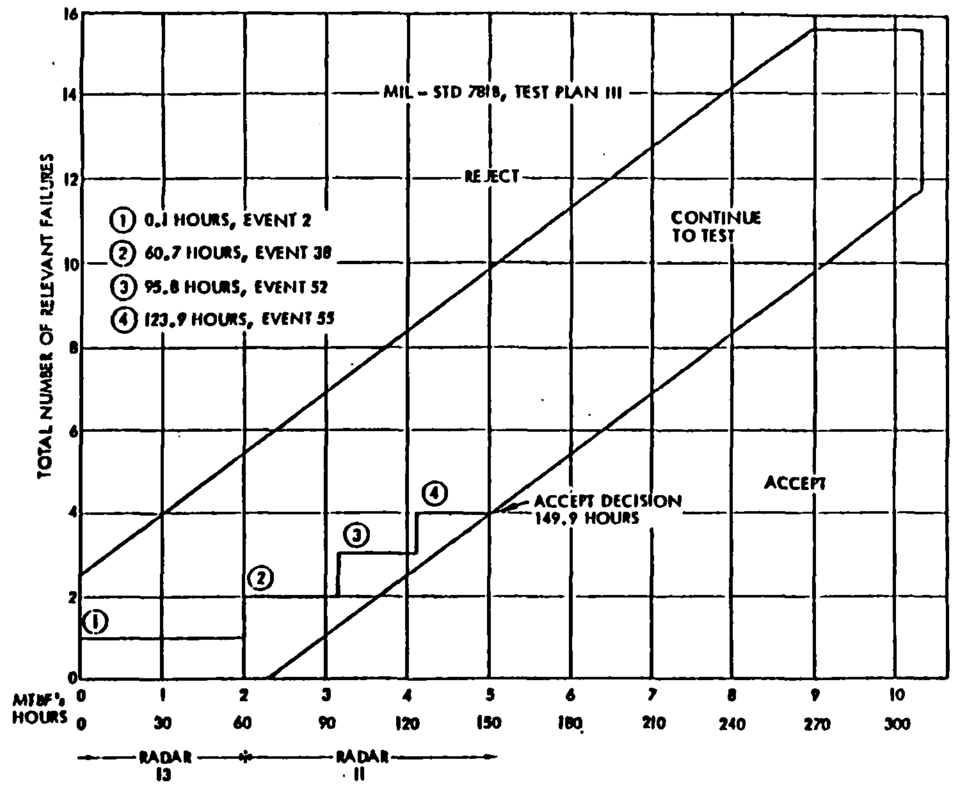
This chart shows the initial Reliability Qualification Test results (Contract-Specified MTBF of 30 hours). The test was conducted on Preproduction Radar Sets 11 and 13 and was successfully completed on the first attempt.

F-15 APG-63 RADAR ENVIRONMENTAL CYCLE RELIABILITY TEST



(A)	START COMPATIBILITY, ACCEPTABILITY OR REPAIR VERIFICATION CYCLE.
(A to B)	INCREASE CHAMBER TEMPERATURE TO 71°C AT 5°C/MIN. AND HOLD FOR 70 MINUTES.
(C to D)	DECREASE CHAMBER TEMPERATURE TO -54°C AT 5°C/MIN.
(D to E)	STABILIZE CHAMBER TEMPERATURE AT -54°C.
(E to F)	INCREASE CHAMBER TEMPERATURE TO -40°C AT 5°C/MIN.
(F to G)	STABILIZE CHAMBER TEMPERATURE TO -40°C AT (1) AND (2), TURN ON LIQUID COOLANT, AND COOLING AIR RESPECTIVELY.
(G to H)	RADAR POWER ON (STANDBY), INCREASE CHAMBER. TEMPERATURE TO 71°C AT 5°C/MIN, COMPLETE SERVICES, TURN-ON.
(H)	INCREASE COOLING AIR PLENUM PRESSURE.
(H to I)	CONTINUE TEMPERATURE INCREASE TO 71°C.
(I to J)	STABILIZE CHAMBER TEMPERATURE AT 71°C.
(J)	INCREASE COOLING AIR AND PLENUM PRESSURE.
(K)	DECREASE COOLING AIR AND PLENUM PRESSURE.
(C' to C)	BEGIN PRT CYCLE, DECREASE CHAMBER TEMPERATURE TO -54°C.

F-15 RADAR REL QUAL TEST
30-HOUR TEST



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HARDWARE CORRECTIVE ACTION SUMMARY

RELIABILITY QUALIFICATION TEST (30 HOURS)

The following charts describe the corrective actions for failures (relevant and non-relevant) that were experienced in this test. Many of these hardware corrective actions were determined for failures that had been experienced in tests prior to RQT (e.g., system burn-in). These corrective actions were not incorporated in the test sample hardware, but in subsequent hardware.

HARDWARE CORRECTIVE ACTION SUMMARY

RELIABILITY QUALIFICATION TEST (30 HOURS)

- ADD PROTECTIVE COVER AND CHANGED MECHANICAL DIMENSIONS TO PROTECT AZIMUTH CABLE WRAP
- INCREASE 001 VCO LOOP AMPLIFIER GAIN TO PROVIDE IMPROVED STANDARDIZATION AND TO REDUCE EXCESSIVE ALIGNMENT TIME
- REVISE MANUFACTURING PROCESS TO PREVENT 001 MODULE SUPPORT BRACKETS FROM BECOMING LOOSE
- CHANGE 001 TO VCO TIMING AND TO AND LO VCO BIAS TO ALLOW COMPENSATION FOR VARIATIONS IN THE VCO TRANSISTOR PARAMETERS
- MODIFY 011 "O" RING GROOVE TO IMPROVE SEALING
- INCORPORATE A ZENER DIODE, JANTXIN4964, TO CLAMP THE OUTPUT OF THE 011 IC 3A1U11 AT A SAFE LEVEL
- ENLARGE HOLES IN JUNCTION BOARDS TO ALLOW SOLDER TO MORE READILY WICK UP TO THE 011 CONNECTOR PINS, ACHIEVING MORE EFFECTIVE CONNECTIONS
- INCORPORATE A HIGHER VOLTAGE RATED TRANSISTOR JANTX2N3637 IN THE 011
- ADD BUFFER AMPS IN 011 TO PROTECT 081 INTEGRATED CIRCUITS

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HARDWARE CORRECTIVE ACTION SUMMARY

RELIABILITY QUALIFICATION TEST (30 HOURS) (CONTINUED)

- CORRECTED 041 WIRE WRAP PLATE WIRE ROUTING AND TENSION
- SEAL THE 011 PREPULSER WAVEGUIDE OPENING WITH WINDOW AND J1, J2 CONNECTIONS WITH SEALING MATERIAL
- ADDED TERMINAL LUGS TO 011 LOGIC SYNCHRONIZER GROUND TO IMPROVE GROUND CONNECTION
- REORIFICE THE 081 326 7131 MODULE TO INCREASE AIR FLOW
- INCREASE THE VALUE OF 011 PREPULSER CAPACITOR TO PREVENT MORE FREQUENT FIRING OF THE SPARK GAP
- CORRECT THE 011 PREPULSER MARGINAL PULSE WIDTH CONDITION TO ALLOW ADJUSTMENT OF THE TRANSMITTER PULSE WIDTH
- INCORPORATE 022 PARAMP TIMING CHANGE
- INCREASE THE GAIN OF THE 039 NET AMPLIFIER HYBRID TO SET THE NET STATUS BIT 2 THRESHOLD ABOVE SYSTEM NOISE
- CORRECT 081 ARTWORK AND ASSEMBLY ERRORS

46A/6-37

SOFTWARE CORRECTIVE ACTION

RELIABILITY QUALIFICATION TEST (30 HOURS)

Software corrective actions were determined for failures experienced in this test. The changes were incorporated into the software during these tests.

SOFTWARE CORRECTIVE ACTION

RELIABILITY QUALIFICATION TEST (30 HOURS)

- DISCONNECT CC FROM CM DURING CM BIT TESTING
- INCREASE GUARD THRESHOLD VALUE FOR LPRF ACQ. 1 TEST
- DO LPRF TEST IN LONG PULSE
- CREATE THREE TIME FAIL COUNTER FOR RANGE DELAY
- REQUIRE CWI POWER TO FAIL 3 TIMES IN A ROW BEFORE SETTING CWI. FAULT IN BIT MATRIX
- ALLOW SWITCH TEST TO RUN FOR TWO MINUTES. SWITCH TEST ELIMINATED IN TP 317000-093 REV D
- REPEAT THE CC MUX TEST 3 TIMES BEFORE SETTING NO-GO
- RESET NO-GO FLAG WHEN BIT MATRIX IS CLEARED
- CHANGE NO-GO CRITERIA FOR "PROCESS SYNCH" BIT TEST FROM 1 TIME TO 3 TIMES PRIOR TO NO-GO
- REQUIRE 75ms WITHOUT PROCESSOR SYNCH SIGNAL BEFORE "PROC SYNC" BIT FAILURE IS SET

46A/6-38

SOFTWARE CORRECTIVE ACTION

RELIABILITY QUALIFICATION TEST (30 HOURS) (CONTINUED)

- CHECK THE 610 OPERATIONAL DISCRETE BEFORE DECLARING A NO-GO. PROVIDES EXTRA INSURANCE IN CASE 610 HAS TRIPPED OFF
- CHANGE 5 MILLIRADIAN WINDOW FOR "ANTENNA IN POSITION" BIT TEST TO 20 MILLIRADIAN WINDOW (TOLERANCE TOO TIGHT)
- RESET NO-GO FLAG WHEN BIT MATRIX IS CLEARED
- INSURE RSP IS IN PROPER MODE WHEN POWER SUPPLY (610 UNIT) TRIPS AND RESTARTS
- PROVIDE A TEST FOR T.O. LOCK AND OFFSET LOCK AT "END OF BAR" AND REQUIRE THREE SUCCESSIVE FAILURES BEFORE SETTING "NO-GO"
- DISABLE VELOCITY UPDATE MODE WHEN RADAR IS IN STANDBY
- CHANGED PROGRAM SO THAT BIT DOES NOT RUN THE RF POWER CHECK WHEN THE 610 UNIT IS NOT OPERATIONAL
- REQUIRES GTWT RF POWER TO FAIL THREE TIMES IN A ROW BEFORE SETTING GTWT RF FAULT IN BIT MATRIX

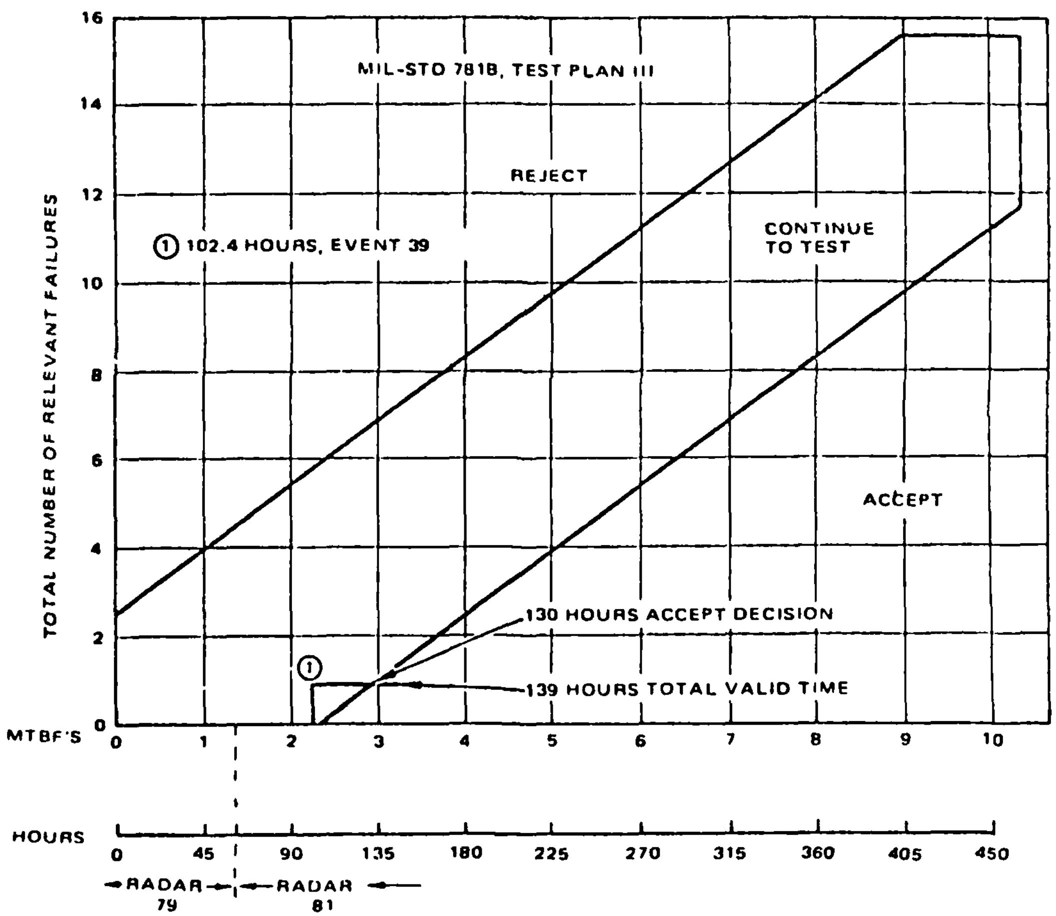
46A/6-39

F-15 RADAR PRODUCTION RELIABILITY TEST

45-HOUR TEST

This chart shows the first Production Reliability Test (Contract-Specified MTBF of 45 hours) results. The test was conducted on Radar Sets 79 and 81 and was successfully completed the first attempt.

F-15 RADAR REL QUAL TEST
45-HOUR TEST



HARDWARE CORRECTIVE ACTION SUMMARY PRODUCTION RELIABILITY TEST (45 HOURS)

The following chart describes the corrective actions for failures (relevant and non-relevant) that were experienced in this test. Most of these hardware corrective actions were determined for failures that had been experienced in tests prior to PRT (e.g., system burn-in). These corrective actions were not incorporated in the test sample hardware, but in subsequent hardware.

HARDWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (45 HOURS)

- 610 10A1 MODULE TEST SPEC REVISED TO INCLUDE VOLTAGE CHECK
- INCREASED WIRE SIZE AND ROUTING FOR WIRE HARNESS TO 081 ETI
- IMPROVED PROCESS SPECIFICATION FOR MANUFACTURE AND INSPECTION OF PRINTED CIRCUIT BOARDS
- CHANGED 081 9A41Q2 TRANSISTOR MOUNTING DESIGN TO REDUCE MECHANICAL INTERFERENCE
- IMPROVED 011 REAR COVER AND SEAL AND INCREASED TORQUE REQUIREMENT
- ADDED A SHIELD AND A DIODE PROTECTION CIRCUIT TO PREVENT STATIC CHARGE AND ARCING FROM CAUSING 011 FAILURES
- REDESIGN POWER TRANSISTOR (PELLETS) USED IN 254266 AND 254268 HYBRIDS
- ISSUED DETAILED PROCESS SPECIFICATION TO DEFINE INSPECTION, CLEANING AND ASSEMBLY OF F-15 RADAR HYDRAULIC COMPONENTS
- ADDED FERRITE BEADS TO CORRECT 022 BEACON OSCILLATOR HIGH TEMPERATURE PROBLEM
- VENDOR ADDED 20X VISUAL INSPECTION FOR 031 CABLE WRAP ETCH IRREGULARITIES
- INSTITUTED 100% INCOMING INSPECTION AND TEMPERATURE CYCLING OF FAULT INDICATORS. VENDOR ADDED TORQUE TEST FOR INTERNAL ASSEMBLY
- REQUIRE HYBRID 254317 TO BE TESTED OVER A TEMPERATURE RANGE OF -55°C TO +100°C PRIOR TO INSTALLATION IN 039 7A2 MODULE

46A/6-40

SOFTWARE CORRECTIVE ACTION PRODUCTION
RELIABILITY TEST (45 HOURS)

Software corrective actions were determined for failures experienced in this test. The changes were incorporated into the software during these tests.

SOFTWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (45 HOURS)

- CORRECT "RANGE DELAY CALIBRATE" BIT INDICATION DUE TO PRESENCE OF EXCESSIVE RF ENERGY IN CHAMBER
- BIT PEAK POWER THRESHOLD CHANGE TO ELIMINATE RF POWER FALSE ALARMS
- IMPROVED BIT PROGRAM TO PERMIT DETECTION OF TACHOMETER PROBLEMS DURING SUPERSEARCH AND BORESIGHT OPERATION

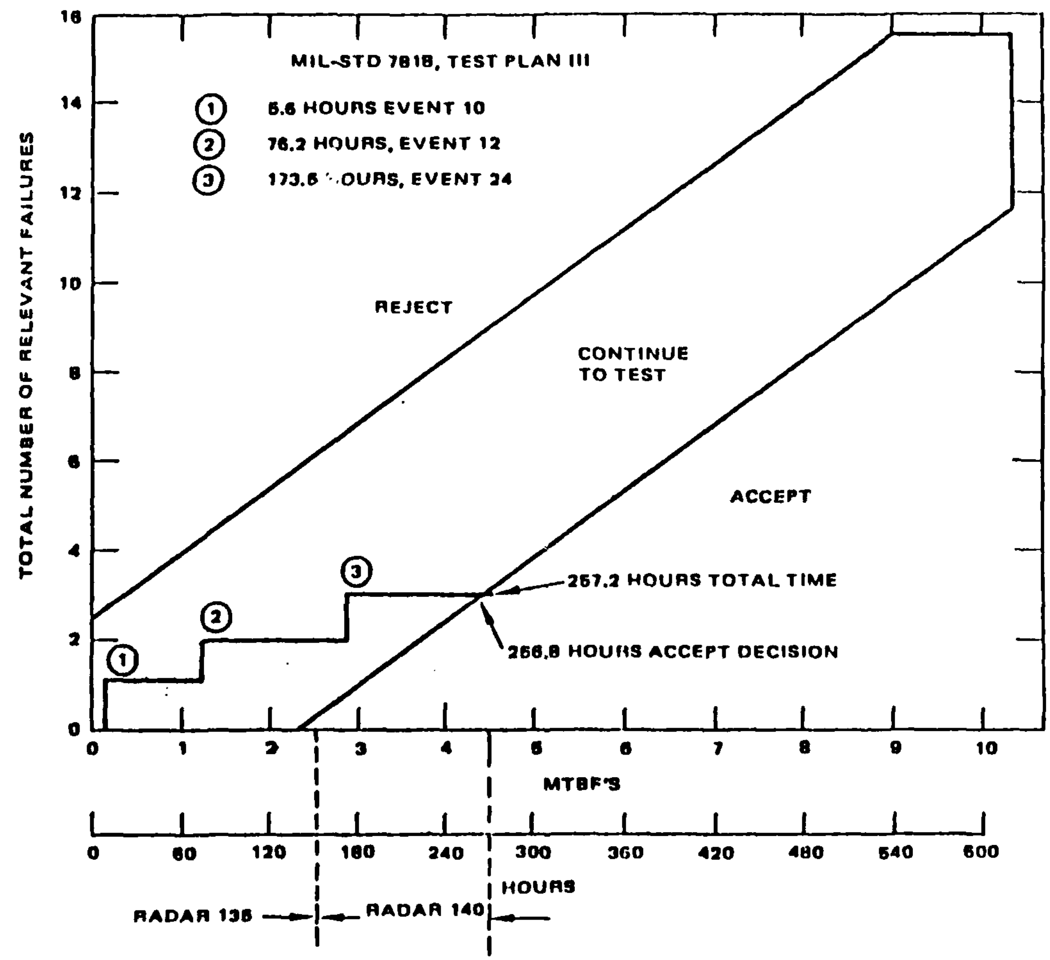
46A/6-41

F-15 RADAR PRT
FIRST 60-HOUR TEST

This chart shows the first PRT with a 60-hour MTBF Contract-Specified requirement. The test was conducted on Radar Sets 135 and 140 and was successfully completed the first attempt.

F-15 RADAR PRT

1ST 60-HOUR TEST

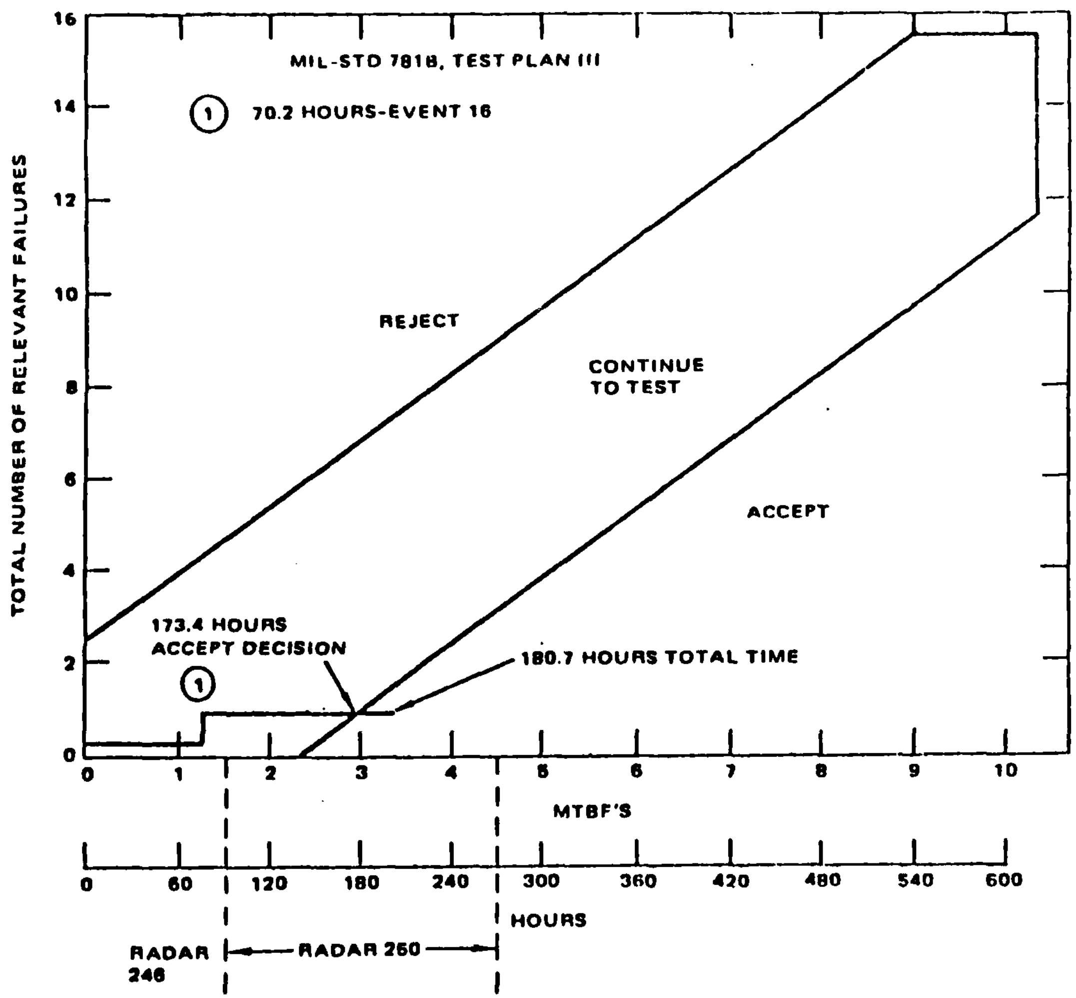


F-15 RADAR SET PRT

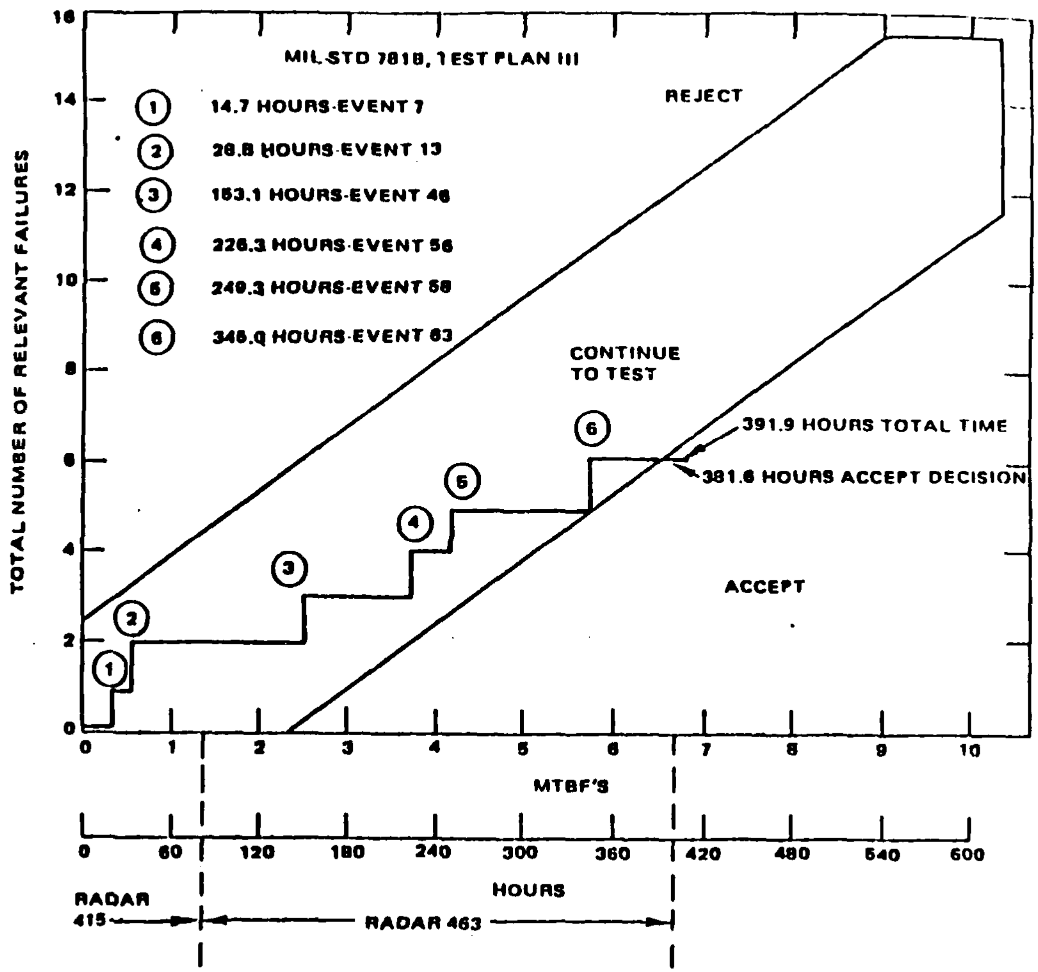
SECOND THROUGH FIFTH 60-HOUR TESTS

The following charts depict the results of each successive 60-hour MTBF PRT. The Test Sample (Two Radar Sets per Sample) is showing at the bottom of the chart. Each test was successfully completed the first attempt.

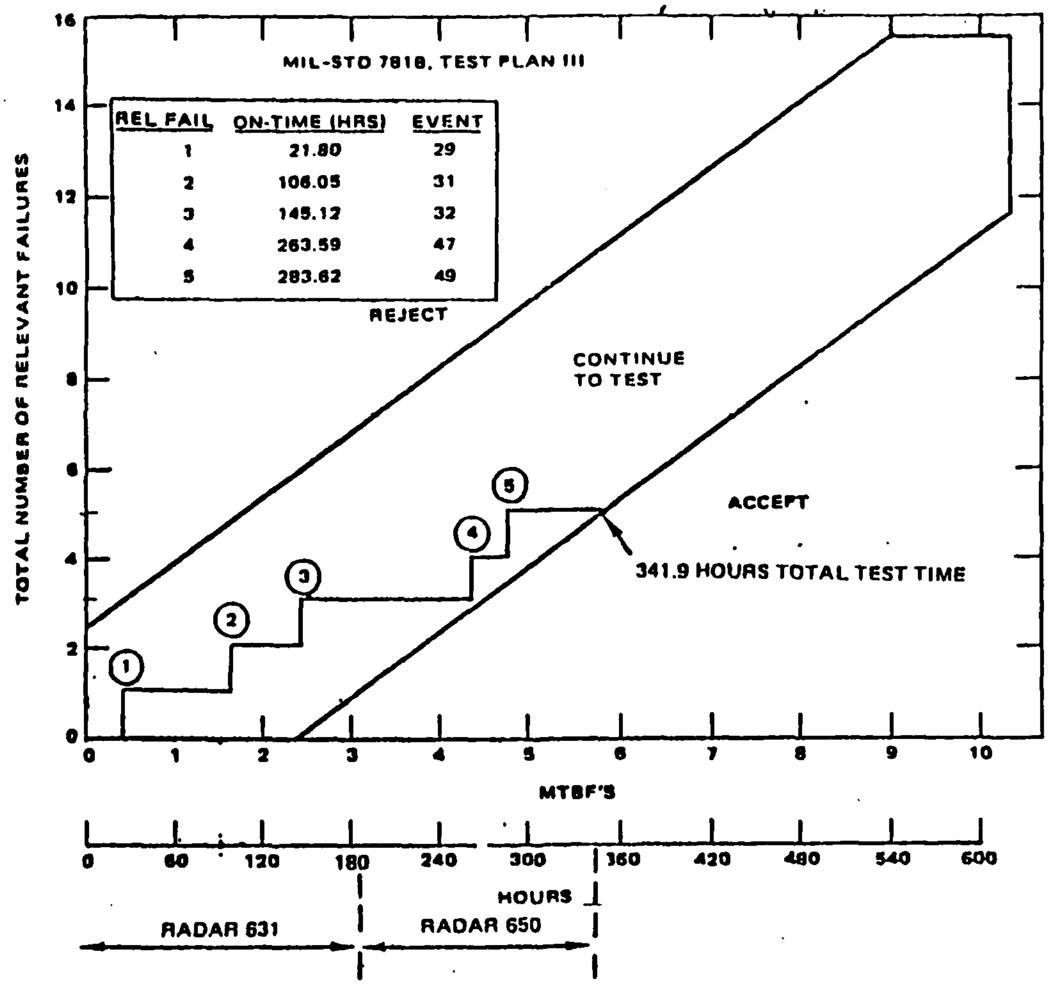
F-15 RADAR PRT
2ND 60-HOUR TEST



F-15 RADAR PRT
3RD 60-HOUR TEST

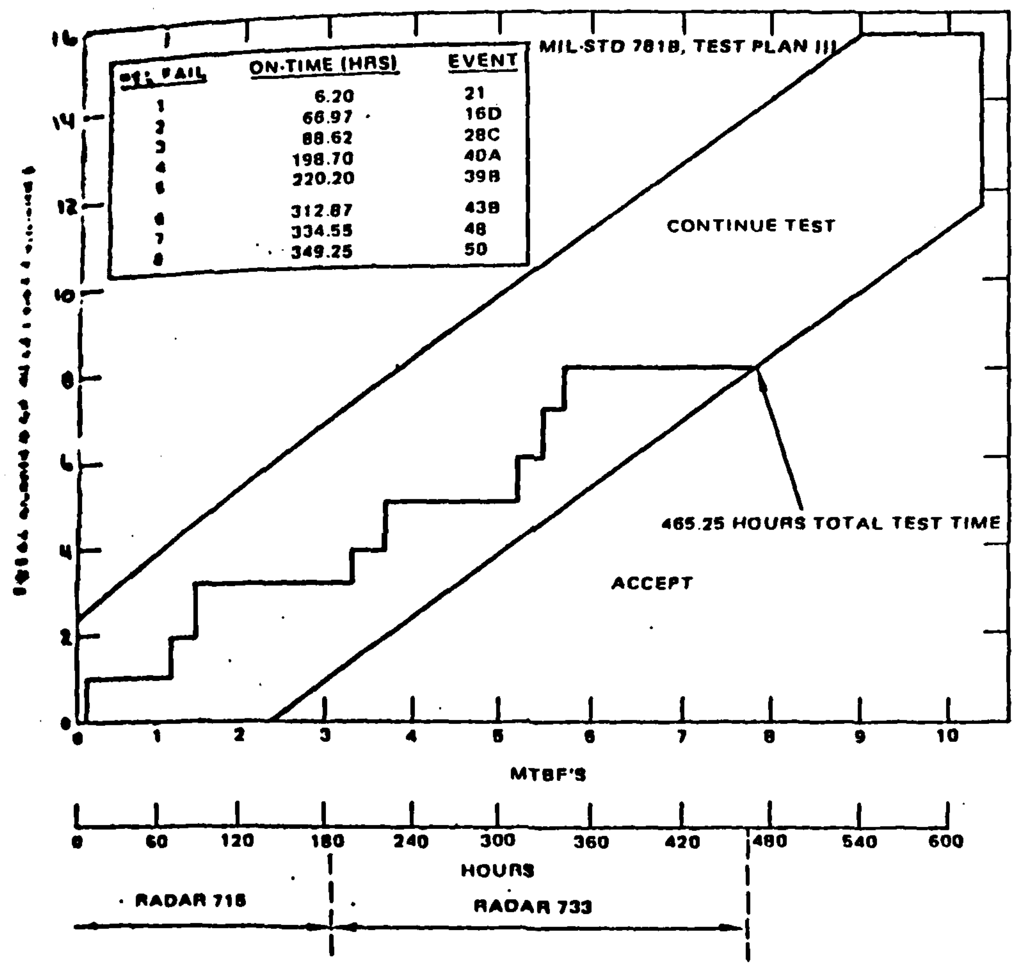


F-15 RADAR PRT
4TH 60-HOUR TEST



REL FAIL	ON-TIME (HRS)	EVENT
1	21.80	29
2	106.05	31
3	145.12	32
4	263.59	47
5	283.62	49

F-15 RADAR PRT
5TH 60-HOUR TEST



HARDWARE CORRECTIVE ACTION PRODUCTION RELIABILITY TESTS (60 HOURS)

The following charts describe the corrective actions for failures (relevant and non-relevant) that were experienced in these tests. Most of these hardware corrective actions were determined for failures that had been experienced in tests prior to PRT (e.g., system burn-in). These corrective actions were not incorporated in the test sample hardware, but *in subsequent hardware.*

HARDWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS)

- LOT OF SOLITRON TRANSISTORS, P/N 928756, PURGED FROM F-15 STORES DUE TO VENDOR MANUFACTURING PROBLEM
- IMPROVED CLEANING AND BONDING INSTRUCTIONS FOR RUBBER COVER OF 541 FRAME STORE CONTROL KNOB. PURGED STORES OF DISCREPANT KNOBS.
- REQUIRE 011 WAVEGUIDE SWITCH (P/N 927050-5B) TO BE TESTED BY VENDOR AT EXTREMES OF VOLTAGE AND TEMPERATURE
- VISUALLY INSPECTED FIFTY HARRIS OPERATIONAL AMPLIFIER CHIPS, P/N 933328-1, AND TESTED TEN IN MANUFACTURING PRIOR TO ASSEMBLY INTO 258323 HYBRIDS TO ENSURE HAC IS GETTING GOOD PARTS
- PROVIDE FOR SPRING LOADING OF 001 VARACTOR DIODE HOLDER TO REDUCE WORKMANSHIP PROBLEMS
- ADD FOUR ON-OFF CYCLES TO HYDRAULIC VALVE VENDOR SCREENING TEST
- REMOVE INTERNAL INCAPSULATION FROM FAULT INDICATORS
- ADDED HARD GROUND WIRE FOR GUARANTEEING PROPER GROUNDING OF 022 5A3A2 MODULE
- THE PROCESSING METHODS FOR THE 610 INTERCONNECT PRINTED CIRCUIT BOARD WERE IMPROVED BY ADDING 16 HOURS OF PREHEAT AND REVISING WAVE SOLDERING SCHEDULES

HARDWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS) (CONTINUED)

- HUGHES PROCEDURES WERE MODIFIED TO ADD 100% VISUAL INSPECTION FOR ALL INTEGRATED CIRCUITS AT MANUFACTURING RECEIVING STATION
- CORE MATERIAL OF P/N 981118 COILS WAS CHANGED TO POWDERED IRON TO MAKE PARTS MORE STABLE WITH TEMPERATURE CHANGES
- VENDOR ADDED 100% INSPECTION FOR P/N 986169 REACTORS TO ENSURE PROPER STRESS RELIEF DURING COIL WINDING
- INCORPORATE LARGER SHOULDER WASHERS TO PROVIDE PROPER INSULATION FOR POWER TRANSISTORS IN THE 610 10A4 MODULE
- CHECK ALL GTWTs IN MANUFACTURING FOR RF LEAKAGE (APPROX. 80)
- CHANGE TAPE FOR PROTECTING TEST ACCESS CONNECTOR TABS TO STRIPLINE LIQUID COATING
- VENDOR IMPROVED PART INSPECTION AND INSULATING QUALITY TO HELP PREVENT FAILURES OF 259220 ENERGIZERS IN THE 081 9A58 MODULE
- CHANGE WIRE BONDING FOR THICK FILM HYBRIDS (LIKE P/N 254272) TO USE GOLD MATERIAL WITH NO GLASS FRIT BINDER
- REPLACE PARALLEL GAP WIRE BONDING OF POWER TRANSISTORS IN F-15 HYBRIDS BY ULTRASONIC LEAD WIRE BONDING

46A/6-43

HARDWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS) (CONTINUED)

- VENDOR USE PETROLATUM (IMPROVED LUBRICANT) FOR O-RING LUBRICATION IN ROLL HYDRAULIC MANIFOLD (P/N 258684-5)
- ADD SLEEVING FOR COAX CABLE AND CHANGE CLAMP FOR ROLL CABLE WRAP (P/N 3402120)
- REDUCE 610 FET NOISE IMMUNITY

  CHANGE 610 10UF CAPACITORS TYPE AND VALUE TO CORRECT FAILURES
- ADD MORE POSITIVE DIMENSION CONTROL FOR ELEVATION CABLE WRAP
- VENDOR CHANGED HUB FINISHING METHOD FOR AZIMUTH ACTUATOR
- REDESIGN THE 011 AUTOMATIC GTWT SATURATION LOOP TO REDUCE TEMPERATURE SENSITIVITY AND TO CORRECT OPERATIONAL PROBLEMS
- VENDOR MODIFIED 011 WAVEGUIDE SWITCH INTERNAL CIRCUITRY TO MAKE PART MORE RELIABLE
- ADD MOLYBDENUM TABS UNDER INTEGRATED CIRCUIT IN 039 7A2U21 HYBRID TO REDUCE TEMPERATURE SENSITIVITY
- CHANGE 031 AZIMUTH CABLE WRAP LAYER LENGTH TO PREVENT WRINKLING
- MODIFY SKEW DIFFERENTIAL SPECIFICATION FOR 042 932849 INTEGRATED CIRCUIT
- MAKE MANUFACTURING TESTERS AND ASSEMBLERS RESPONSIBLE FOR CLEANING 001 AND 022 MINIATURE COAX CABLES

46A/6-44

HARDWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS) (CONTINUED)

- REPLACE 031 TACHOMETER BY BRUSHLESS TYPE
- REPLACE 042 12A28 928883-1B POWER TRANSISTOR WITH IMPROVED TYPE 928883-4B OR H980022-1B PARTS
- CHANGE COAX CABLE ROUTING ON 001 1A5A1 MODULE
- VENDOR TO INSTITUTE 100% VIBRATION AND SHOCK TESTING OF FAULT INDICATORS
- VENDOR INSTITUTE IMPROVEMENT IN APPLYING BEARING LUBRICANT TO 031 GYROS
- REDESIGN 081 INVERTER POWER SUPPLY TO IDENTIFY POTENTIAL EAROM MEMORY FAILURES
- MODIFY RADAR ACCEPTANCE TEST PROCEDURE TO SPECIFY CHANNEL FIVE FREQUENCIES

46A/6-45

SOFTWARE CORRECTIVE ACTION PRODUCTION
RELIABILITY TESTS (60 HOURS)

Software corrective actions were determined for failures experienced in this test. The changes were incorporated into the software during these tests.

SOFTWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS)

- CORRECT BEACON OSCILLATOR TURN-OFF SIGNAL TIMING DURING INITIATED BIT TO CORRECT ASYNCHRONOUS OPERATION
- CHANGE "NET 2" BIT TEST TO A THREE-TIME FAILURE CRITERIA
- CORRECT "041 IDA INTERRUPT" MODE CHANGE ROUTINE ANOMALY
- CORRECT PROGRAM ERROR IN "ANT IN POS" BIT TEST
- CORRECT 039 "MEDIAN PRF TRACK GAIN BALANCE" BIT INDICATION
- CHANGE "SCAN RATE" BIT TEST TO A THREE-TIME FAILURE CRITERIA
- PROVIDE FOR RETURN TO "PROCESS SYNCH" WHEN REAL-TIME CLOCK SELECTED IF PROCESS SYNCH PULSES RETURN DURING A MODE CHANGE
- PROVIDE "PROCESS SYNCH" BIT FAILURE INDICATION ONLY IF PROCESS SYNCH PULSES ARE MISSING CONTINUOUSLY FOR TWO SECONDS
- CORRECT BIT "COOLANT" FAILURE LOGIC
- WIDEN "MPRF GAIN BAL" BIT TEST TOLERANCE

SOFTWARE CORRECTIVE ACTION

PRODUCTION RELIABILITY TEST (60 HOURS) (CONTINUED)

- CORRECT HARDWARE/SOFTWARE INCOMPATIBILITY WHICH CAUSED INCORRECT "HPRF TK" BIT FAILURE INDICATION
- PROVIDE INDICATION OF A BIT FAILURE ONLY WHEN A FAULT INDICATOR FAILS TO SET IN A FAULT AT POWER-DOWN
- PROVIDE FOR RESETTING OF ALL FAULT INDICATORS AFTER 081 SELF TEST IS COMPLETED OR WHEN INITIATED BIT IS COMPLETED
- CHANGE "PROC SYNCH" BIT TEST TO A THREE TIMES FAILURE CRITERIA
- USE HIGHER PRF WAVEFORM TO GENERATE "RFLPRF" BIT INDICATION
- CORRECT "IDA INTERRUPT" PROCESSING TO REDUCE ANTENNA HANG-UPS
- REINITIATE BIT TEST IF "IDA INTERRUPT" SIGNAL LOSS OCCURS UNLESS "IDA" SIGNAL LOST DURING THREE SUCCESSIVE TESTS

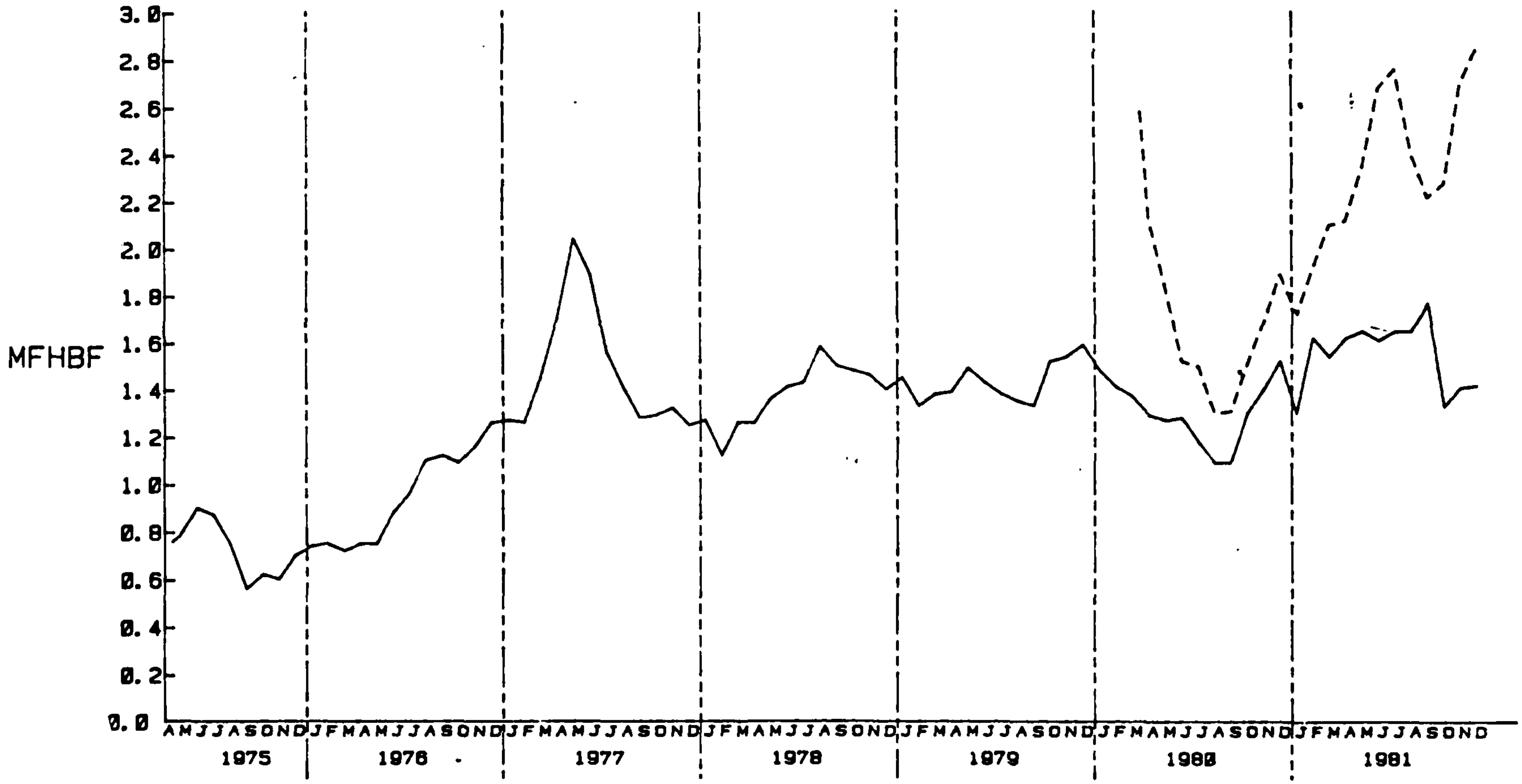
46A/6-47

AIRCRAFT RELIABILITY TREND, D056B5006

AFM 66-1 MAINTENANCE DATA REPORTING BEGAN UPON DELIVERY OF THE FIRST F-15 AIRCRAFT TO LUKE AFB IN NOVEMBER 1974. THESE MAINTENANCE DATA WERE SORTED BY AFLC IN ACCORDANCE WITH THE COMPUTER LOGIC OUTLINED IN AFR 66-15 AND COMBINED WITH THE AIRCRAFT FLIGHT TIME TO PRODUCE THE D056B REPORTS. ALTHOUGH NOT DIRECTLY COMPARABLE TO THE SPECIFIED MTBF, THE RESULTANT MEAN-FLIGHT-HOURS-BETWEEN-FAILURE (MFHBF) OR MEAN-TIME-BETWEEN-MAINTENANCE-TYPE 1 (MTBM-1) AS IT WAS SUBSEQUENTLY RENAMED PROVIDES AN INDICATION OF RELIABILITY LEVELS AND TRENDS. IT SHOULD BE NOTED THAT NUMERICAL VALUES FREQUENTLY DART UP AND DOWN BECAUSE INPUT DATA ARE LOST OR DELAYED, SPECIAL INSPECTIONS UNCOVER PREVIOUSLY UNDETECTED DISCREPANCIES, FUEL ALLOCATIONS ARE INCREASED TO PERMIT MORE FLYING, ETC.

F-15 RELIABILITY TREND

(AF D056B REPORTS USING AFM 66-1 DATA)



THE GRAPH PLOTS THREE MONTH MOVING AVERAGES

—— F-15 A/B

- - - F-15 C/D

SPECIFICATION VS AFM 66-1 RELIABILITY

The reliability of the F-15, its subsystems and major components was specified in terms of a MTBF based on operating hours and relevant failures, whereas the only available measure after formal demonstrations were completed is the AFM 66-1 data based on flight hours and Type 1 maintenance action as determined by the AFLC computer logic. An overall relationship between these values was estimated at 3:1 by USAF in 1977.

"....AF OPERATING COMMAND FOR THE F-15 EXPECTS THE MEAN TIME BETWEEN FAILURE CONTRACT GOAL OF 3.5 HOURS TO AMOUNT TO 1.13 FLIGHT HOURS IN THE OPERATIONAL ENVIRONMENT." (A RATIO OF 3:1)

(GAO REPORT TO SENATE APPROPRIATIONS COMMITTEE, OCTOBER 1977)

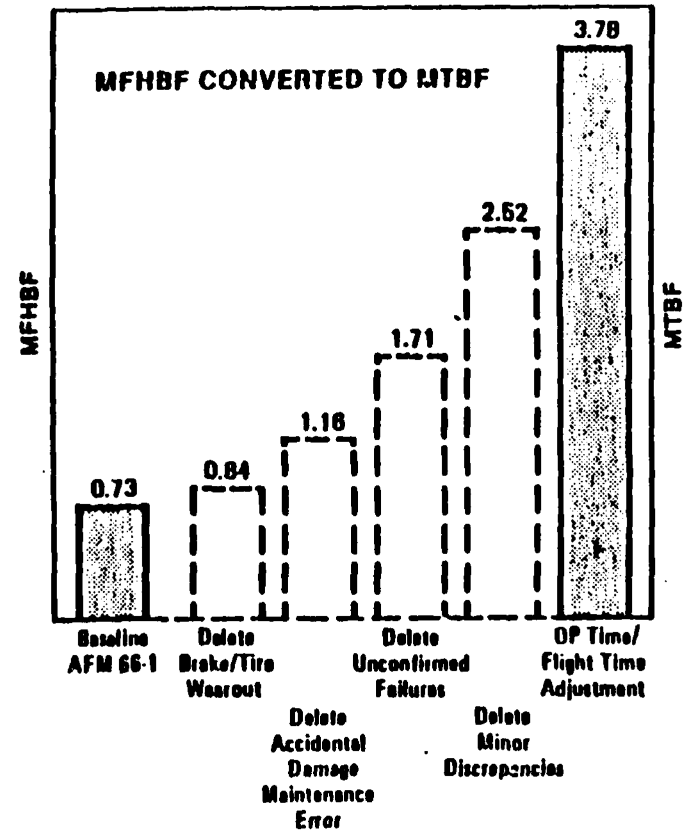
46/1-35

MFHBF CONVERTED TO MTBF

The MFHBF reported by DO56B includes as "failures" many maintenance actions that would not be counted in formal reliability demonstration testing. The facing chart illustrates how removal of those non-changeable events and correction for operating time, in lieu of flight time, produces a MTBF that can be compared to specification requirements.

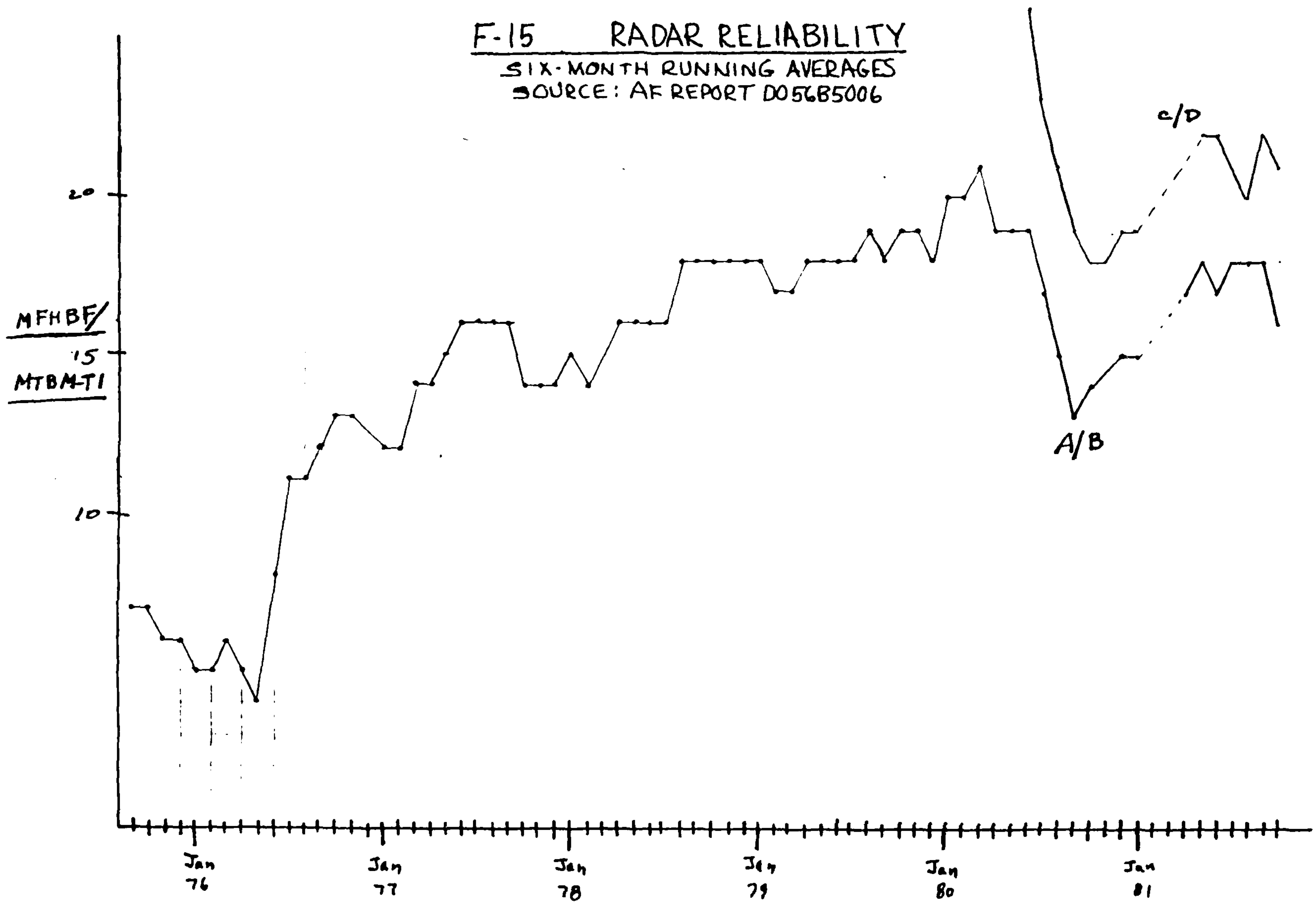
RADAR MTBF OVER THREE TIMES MFHBF

BASED ON HISTORICAL DATA FOR TOTAL AIRCRAFT IN 1976 TIME PERIOD



RADAR RELIABILITY TREND, D056B5006

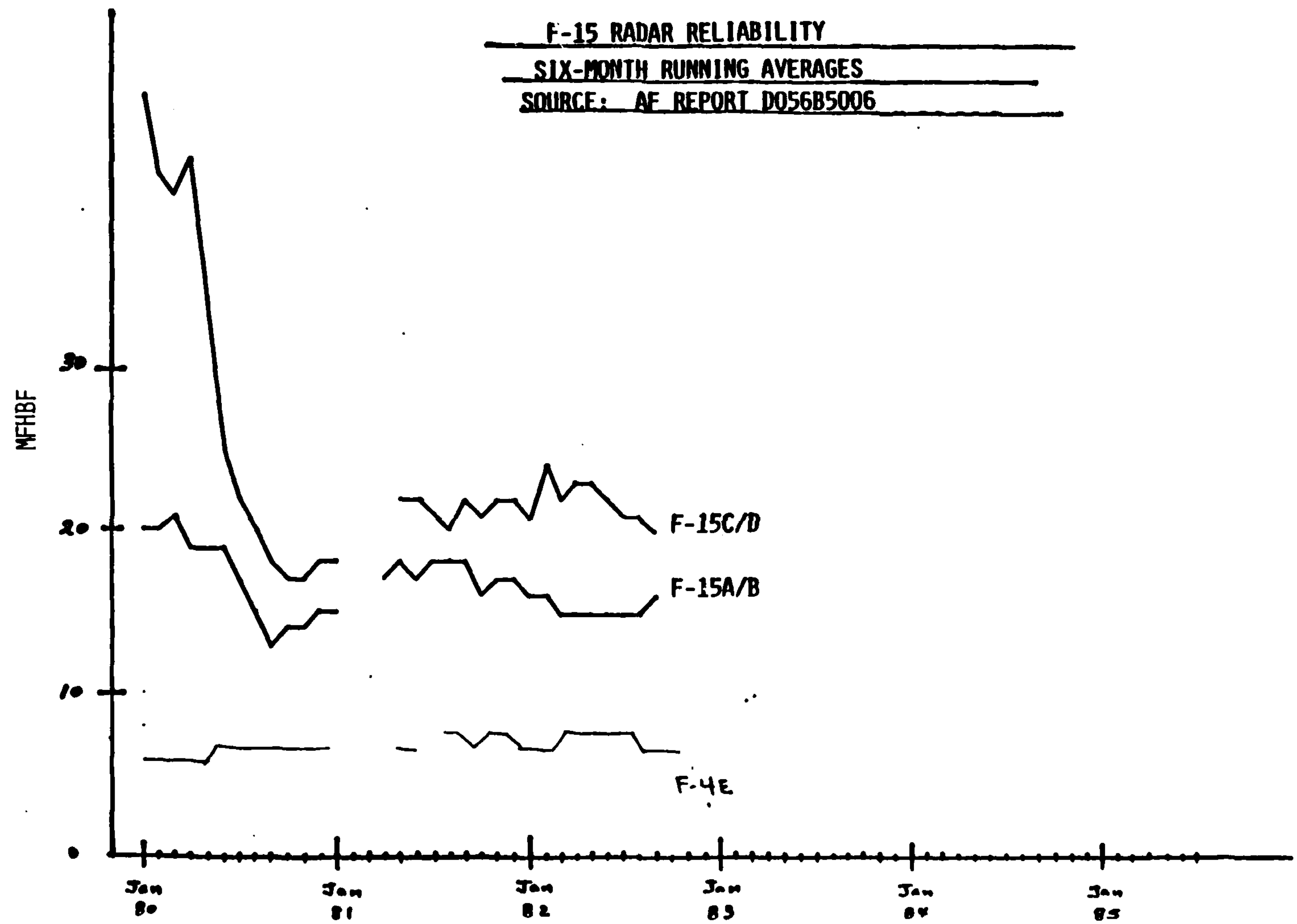
The Radar Reliability Trend shown by the AFM 66-1 data shows the same early growth as the aircraft, and indeed, was one of the major causes. Reliability improvements were being generated from McAir's Eagle Watch Program, integrated corrective action program (ICAP), the production reliability sample tests, and Hughes ongoing production screening/burn-in and corrective action efforts. The early improvements were expedited by HAC field teams who went from base to base to incorporate the modifications. The first team worked from June 1975 to May 1976 incorporating ECPs 260, 332, 377, 405, 565, 566 and 600, and a second team worked from May 1976 to August 1977 to incorporate ECPs 649, 660, 661, 702, 726, 727 and 762.


F-15 RADAR RELIABILITY
SIX-MONTH RUNNING AVERAGES
SOURCE: AF REPORT D056B5006
MFHBF/
MTBM-TI
20
15
10
C/D
A/B
Jan 76
Jan 77
Jan 78
Jan 79
Jan 80
Jan 81

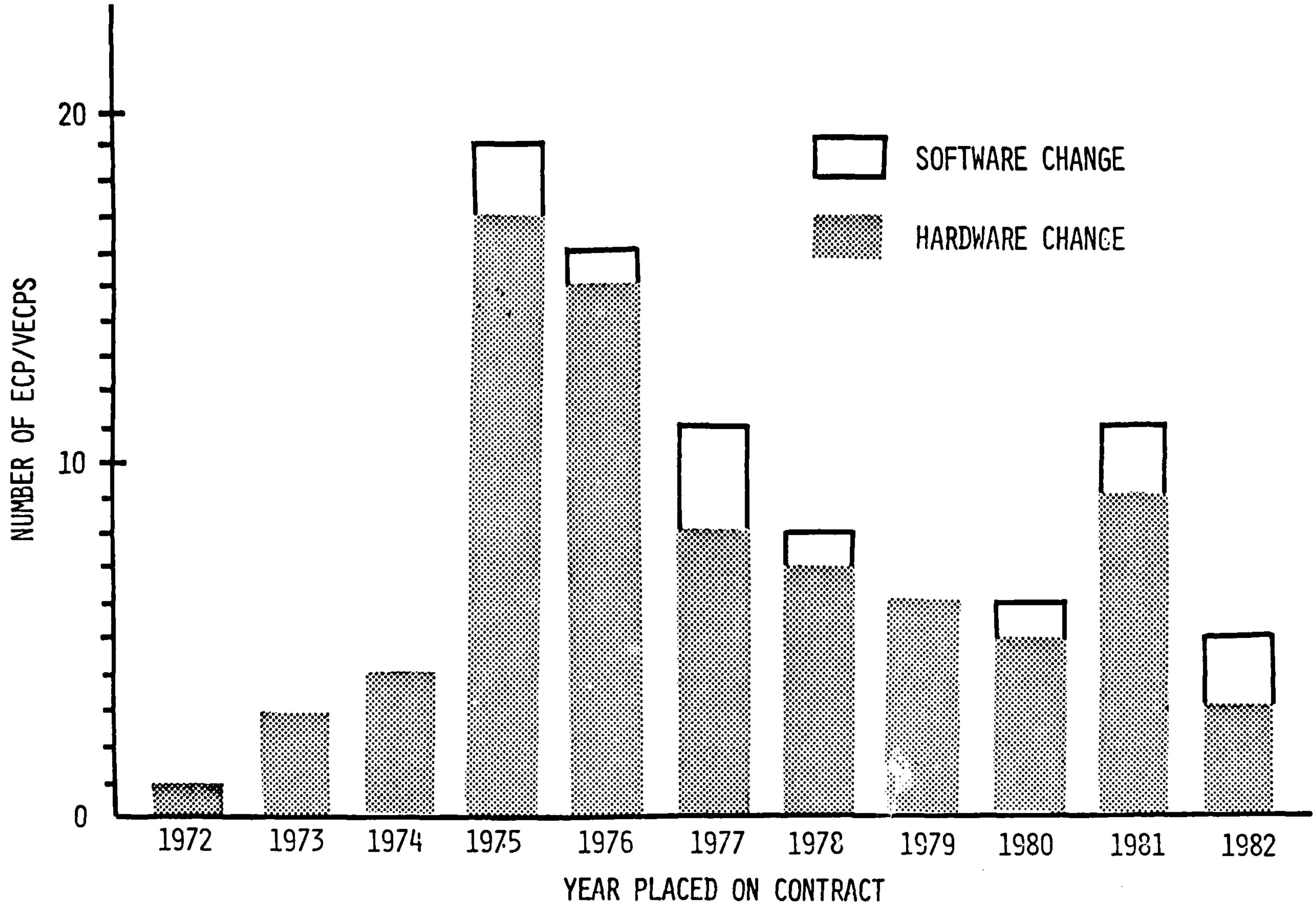
RADAR RELIABILITY TREND, DO56B5006
(continued)

The DO56B radar data for 1980 through 1982 illustrates two points which frequently apply to all aircraft.

- The initial MFHBF is usually high, but drops after a few months. This results from aircraft being delivered with all new equipment, thus there are no replacements of life-limited items or need for periodic inspection/corrosion control in the first few months. In addition, the MFHBF is calculated on the basis of flight hours and maintenance reports received during this month, thus optimistic values are initially generated because the flight time is all reported at the end of the month while the maintenance data may lag by as much as six months.
- The computer logic for the DO56B reports is changed from time to time, making it difficult to compare data from different time periods. A change was introduced in early 1981 resulting in about a 6% to 10% improvement in reported MFHBF.


F-15 RADAR RELIABILITY
SIX-MONTH RUNNING AVERAGES
SOURCE: AF REPORT D056B5006
MFHBF
30
20
10
0
F-15C/D
F-15A/B
F-4E
Jan 80
Jan 81
Jan 82
Jan 83
Jan 84
Jan 85

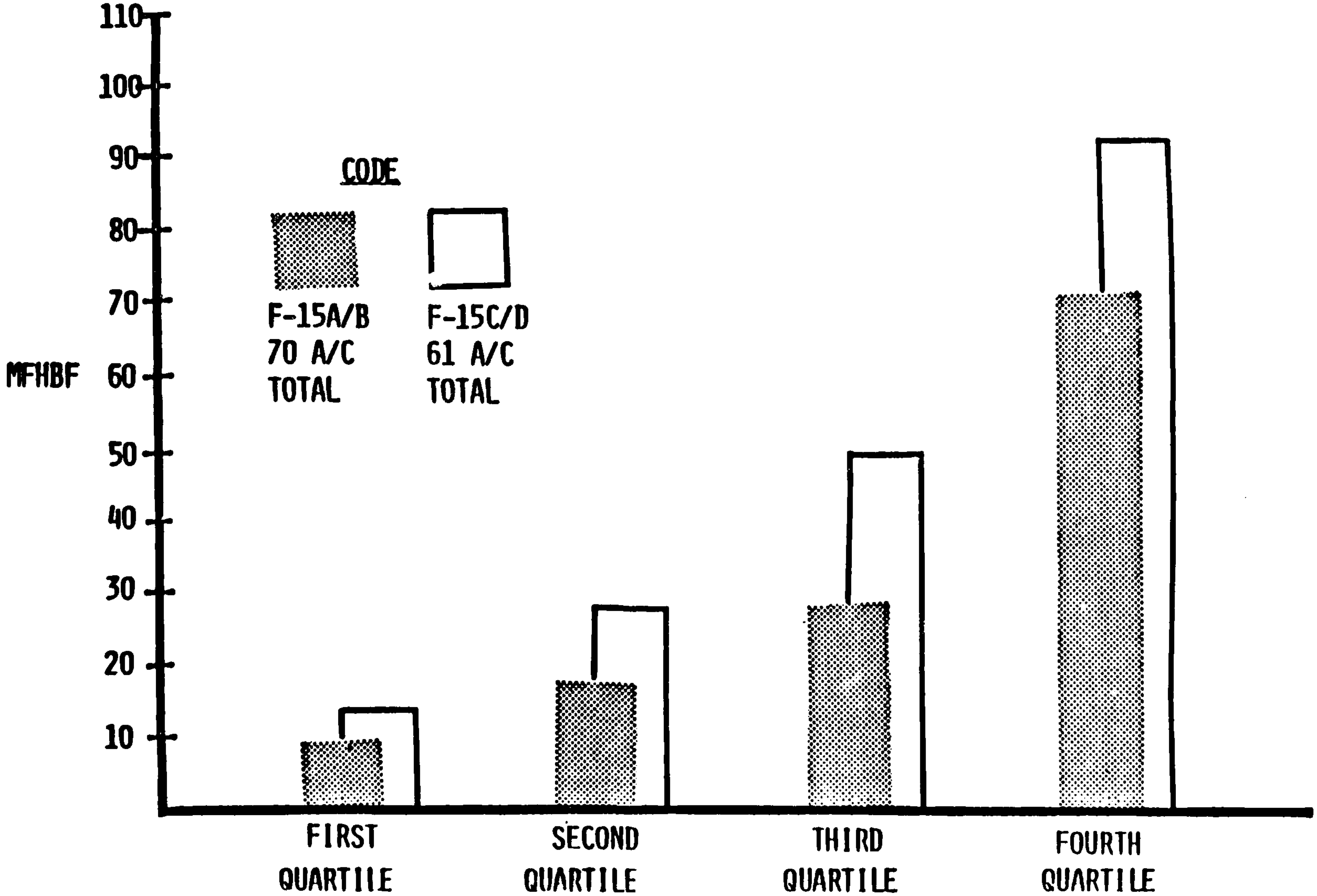
RADAR CONFIGURATION CHANGES



RADAR MFHBF AT BITBURG AFB

It became possible to compare the relative reliability of F-15A/B vs the later F-15C/D radars when earlier model aircraft were replaced, a few at a time, at Bitburg AFB. Missions, maintenance, environments and reporting were the same, but most of the radar LRUs were interchangeable, thus assets could gradually be mixed between the aircraft models. Data were first sorted by model and then grouped by Quartile (group with lowest MFHBF, etc). It was found as expected that the radars in the F-15C/D had a higher MFHBF. As shown by the facing chart, there was a very wide range of individual aircraft values, with some aircraft flying for months without a radar failure, while a few "hanger queens" had a succession of failures (often the same LRU type) within a few hours.

RADAR MFHBF AT BITBURG AB
(AFM 66-1 DATA PER D056B COMPUTER LOGIC)
AUGUST 1980 - JULY 1981



LRUs RANKED BY AFM 66-1 DATA

The AFM 66-1 data indicate that the radar reliability has been limited by the high power, analog and electro-mechanical components (antenna and transmitter). The LRUs consisting primarily of digital circuits (digital processor and digital target processor) have achieved very high reliability levels despite high parts concentration.

F-15 C/D RADAR

LRUs RANKED BY AFM 66-1 FAILURE RATE

APRIL THROUGH SEPTEMBER 1982

ITEM		WUC	MFHBF	PERCENTAGE OF TOTAL FAILURES
ANTENNA	(031)	74FU0	106	21
TRANSMITTER	(011)	74FA0	142	16
ANALOG PROC.	(039)	74FS0	151	15
DIGITAL PROC.	(081)	74FQ0	186	12
POWER SUPPLY	(061)	74FH0	261	10
RECEIVER	(022)	74FC0	310	7
DIG. TGT. PROC./ PROG. SIGN. PROC.	(041/042)	74FF0/ 74FY0	420	5
EXCITER	(001)	74FJ0	437	5
SET CONTROL	(541)	74FK0	3690	1
LRU NOT IDENTIFIED				7
SET TOTAL			22.4	100

46A/6-48

F-15 RADAR M VERIFICATION RESULTS

Verification of the Radar M quantitative requirements was demonstrated in accordance with MDC Report G117 and conducted in conjunction with the Reliability Qualification Test. The M test objective was to determine if the specified requirements for Maintenance Man-hours To Repair (MMTR) and Mean Time Between Maintenance Actions (MTBMA) had been achieved. The demonstration was done at Hughes Aircraft Company, El Segundo facility, on Radar Sets Numbers 11 and 13. Additional data from Preliminary and Post Reliability Qualification Test was needed and utilized in order to provide an adequate sample size. In all, a total of 52 samples were analyzed and 1159 operating hours were evaluated in determining verification results.

The MMTR of the F-15 Radar System was calculated to be .365 hours, which is approximately 47% of the specification value. The 52 maintenance tasks experienced on 2 Radar Sets over a period of 12 months provided a realistic presentation of the Radar MMTR. The MTBMA demonstrated by Radar Sets 11 and 12 during the Reliability Qualification Test was 22.29 hours. The demonstrated value exceeds the specified value of 15 hours by a factor of 1.5.

EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

All How Malfunction Codes (except No Defect and Invalid Codes) and the following Action Taken Codes are used to test reported actions for qualification as an abort:

Code	Description
F	Repair
G	Repair and/or Replacement of Minor Parts, Hardware, and Soft Goods
K	Calibrated - Adjustment Required
L	Adjust or Reset
P	Removed
R	Remove and Replace
Z	Corrosion Treatment

Occurrences - This is the number of occurrences reported for the current month and each of the preceding five months against the listed work unit code. The accumulation is based on an occurrence (a count of one (1) per card) rather than a unit count. Cards with zero (0) units completed are excluded from this count. Also, only selected How Mal and Action Taken combinations are considered. These occurrences are determined and listed as the following types:

(Prior to March 1981)

Fail - This column displays failure occurrences.

(1) The computer definition describing a failure occurrence at the five position work unit code level is:

(a) Any Type 1 How Malfunction code in combination with an Action Taken code F, K, L, or Z.

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EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

(Prior to March 1981)

(b) Any Type 1 How Malfunction code in combination with an Action Taken code of P or R provided the removed item was not found serviceable ("B" Action Taken code) at the bench check station.

(2) The computer definition describing a failure occurrence and the accumulation of failures for use in displaying data at the system/subsystem level (74XXX/741XX) is the same as paragraph (1) above plus "G" Action Taken codes reported in combination with any Type 1 How Malfunction code. Accumulation of failure occurrences as related to "G" Action Taken code for display at system/subsystem level (74XXX/741XX) is further limited to a count of one (1) per job control number after first qualifying as an occurrence.

<u>Oth Mal</u> - This column displays other malfunction occurrences which *are defined as:*

(1) Any Type 1 How Malfunction code in combination with an Action Taken code of "G" at the five position work unit code level. The other malfunction occurrence accumulation and display at the system/subsystem level (74XXX/741XX) is not a direct accumulation of other malfunction occurrences of each WUC within the system/subsystem because at this level a part of the other malfunction occurrences are displayed as failures.

(2) Type 2 How Mal Code and all Action Taken codes F, G, K, L, P, R, and Z.

<u>Total</u> - These are the total occurrences reported under all <u>valid</u> How Malfunction codes (Type 1, 2, and 6) and all Action Taken codes plus E, H, J, S, V, and X.

<u>NOTE:</u> A listing of the specific How Malfunction codes in each of these types is contained in AFLCM 66-15, Chapter 5, Section B.

46B/4-2

EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

(Prior to March 1981)

MTB - This is the mean time between failure or maintenance as indicated by the following two sub-headings:

a. FAIL - The mean time between failure (MTBF) is computed each month on the work unit code unless there are no reported failures for any three consecutive months within time span covered by this report. For each monthly MTBF computation, a three-month accumulation of failures and operating time (flying hours or days) is used, i.e., current and previous two months. Following is the formula employed:

$$\text{MTBF} = \frac{\text{Operating Time x Use Factor x QPA}}{\text{Quantity of Failure Occurrences}} \times \frac{\text{Special Inventory}}{\text{AFM 65-110 Inventory}}$$

where:

Operating Time	=	a three-month (current and previous two months) accumulation of flying hours or days whichever applies.
Use Factor	=	Ratio of item operating time to flying hours. Normally 1.00.
Quantity per Assembly	=	Number of identical items reportable under one work unit code.
Quantity of Failures	=	A three-month (current and previous two months) accumulation of failure occurrences.
Special Inventory		
AFM 65-110 Inventory		

EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

(Prior to March 1981)

b. MAINT - The mean time between maintenance (MTBM) is computed each month on the work unit code using the same formula and criteria as for MTBF with one exception, i.e., quantity of total occurrences is substituted for quantity of failure occurrences.

(After March 1981)

Maint Actions - This is the number of maintenance actions reported for the current month and each of the preceding five months against the listed work unit code. The accumulation is based on a count of units completed on maintenance actions with selected How Mal and Action Taken combinations. These actions are determined and listed as follows:

a. (Fail) Type 1 - This column displays failures. The computer definition of a failure at the two, three, and five position work unit code level is:

(1) Any Type 1 How Malfunction code in combination with an Action Taken code of F, K, L, or Z.

(2) Any Type 1 How Malfunction code in combination with an Action Taken code of P or R provided the removed item was not found serviceable ("B" action taken code) at the bench check station.

b. Type 2 - This column displays other malfunction actions which are defined as: Type 2 How Malfunction code and all Action Taken codes.

c. Total - These are total maintenance actions (units) reported under all valid How Malfunction codes (Types 1, 2, and 6) and all Action Taken codes F, G, K, L, P, R plus E, H, J, S, V, and X.

EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

(After March 1981)

MTBM - This is the Mean Time Between Maintenance Type 1 or Mean Time Between Maintenance Total as indicated by the following two subheadings:

a. Type 1 - The Mean Time Between Maintenance Type 1 (MTBM-1) is computed each month for each work unit code unless no failures have been reported for any three consecutive months within time span covered by this report. For each monthly MTBM-1 computation, a three month accumulation of failures and operating time (flying hours or days) is used, i.e., current and previous two months. Following is the formula:

$$\text{MTBM-1} = \frac{\text{Operating Time x Use Factor x QPA}}{\text{Quantity of Failures}} \text{ x Inventory Ratio}$$

where:

Operating Time	= A three month (current and previous two months) accumulation of flying hours. Adjusted by inventory X days, as applicable.
Use Factor	= Ratio of item operating time to flying hours. (Normally 1.00)
Quantity per Assembly	= Number of identical items reportable under one work unit code.
Quantity of Failures	= A three-month (current and previous two months) acccumulation of failures.
Inventory Ratio	= B4 special inventory divided by AFR 65-110 inventory.

EXCERPTS FROM AIR FORCE GROUND RULES USED TO PREPARE DO56B

(After March 1981)

b. Total - The Mean Time Between Maintenance total is computed each month for each work unit code using the same formula and criteria as for MTBM-1 with one exception, i.e., quantity of total maintenance actions is substituted for quantity of failures.

SUMMARY OF CHANGE

Prior to March 1981, Action Taken Code G - Repair and/or Replacement of minor parts, etc., was counted in calculating the MTBM.

Subsequent to March 1981, Action Taken Code G was not counted. It is believed that this change had a small impact on radar MTBM values, although it did significantly affect other systems in the airplane, such as engines.

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1975

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN							
FEB							
MAR							
APR	194	20	0	75	11	3	
MAY	244	27	1	97	10	3	
JUN	320	33	0	80	9	3	758
JUL	257	37	4	81	8	3	164
AUG	326	66	0	133	7	3	226
SEP	238	56	0	145	5	2	205
OCT	511	50	3	128	6	3	358
NOV	322	82	4	152	6	3	153
DEC	495	97	8	156	6	3	86

52/28-1

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1976

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	636	124	4	214	5	3	91
FEB	718	129	10	261	5	3	84
MAR	928	108	4	254	6	3	127
APR	968	109	6	276	8	3	131
MAY	1023	111	2	308	9	3	243
JUN	1169	99	4	334	10	3	263
JUL	2359	113	1	282	14	5	650
AUG	1660	169	12	391	14	5	305
SEP	1795	168	6	342	13	6	306
OCT	1787	113	5	385	12	5	228
NOV	2260	157	17	578	13	4	209
DEC	2286	153	8	539	[illegible]	4	211

52/28-2

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1977

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	2469	234	6	566	13	4	226
FEB	2589	231	9	651	12	4	319
MAR	3259	157	12	455	13	5	308
APR	2103	117	2	303	16	6	346
MAY	4183	222	10	523	19	7	398
JUN	3925	216	7	557	18	7	537
JUL	2431	221	7	560	16	6	439
AUG	4525	316	9	655	14	6	473
SEP	3719	253	5	564	14	6	508
OCT	4061	353	11	655	13	7	492
NOV	5202	302	23	646	14	7	333
DEC	3844	264	18	659	14	7	252

52/28-3

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1978

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	3844	213	19	636	17	7	215
FEB	4262	337	32	917	15	5	173
MAR	5549	312	18	842	16	6	198
APR	5159	311	10	766	16	6	250
MAY	5852	362	20	944	17	6	345
JUN	6486	360	17	909	17	7	372
JUL	5158	301	19	911	17	6	312
AUG	7047	331	18	832	19	7	346
SEP	6320	373	18	823	18	7	337
OCT	6593	399	16	863	18	8	384
NOV	6187	306	25	628	18	8	324
DEC	6057	419	24	936	17	8	290

52/28-4

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1979

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	6789	371	23	859	17	8	264
FEB	6387	422	22	880	16	7	279
MAR	8268	479	19	1022	17	8	335
APR	8259	370	22	898	18	8	364
MAY	8314	383	7	885	20	9	51[illegible]
JUN	8075	476	15	1126	20	8	560
JUL	7765	485	20	1064	18	8	575
AUG	8955	487	19	1138	17	7	459
SEP	7028	471	13	1025	16	7	457
OCT	8998	330	18	856	19	8	500
NOV	8078	380	18	928	20	9	492
DEC	6866	425	11	984	21	9	509

52/28-5

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1980

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	7868	330	13	798	20	8	543
FEB	7144	371	20	841	19	8	497
MAR	7039	380	22	973	20	8	401
APR	8006	394	17	956	19	8	376
MAY	6443	391	21	947	18	7	358
JUN	6922	462	31	978	17	7	310
JUL	6103	545	30	1117	14	6	237
AUG	6586	523	27	1085	13	6	223
SEP	6256	432	22	965	13	6	240
OCT	8147	484	18	1047	15	7	313
NOV	5995	418	27	947	15	7	304
DEC	6527	266	15	627	18	8	344

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1981

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	[illegible]	552	20	1242	16	7	172
FEB	[illegible]2	398	43	924	17	7	158
MAR	7728	369	35	1012	16	7	145
APR	7711	427	62	1101	19	7	160
MAY	6761	393	53	909	19	7	148
JUN	6852	373	47	912	18	7	132
JUL	7214	391	32	854	18	8	158
AUG	6156	449	37	905	17	8	174
SEP	5878	332	17	757	16	8	224
OCT	7483	460	32	965	16	7	227
NOV	5209	363	34	823	16	7	224
DEC	6685	401	33	957	16	7	196

52/28-7

F-15 A/B APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1982

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	5086	345	28	860	15	6	179
FEB	6778	530	22	1063	15	6	223
MAR	7860	551	44	1194	14	6	210
APR	7835	391	20	801	14	7	261
MAY	7309	476	24	892	15	7	261
JUN	7388	435	22	831	17	9	341
JUL	6277	568	45	1151	14	7	230
AUG	7738	363	19	745	16	8	249
SEP	6106	449	32	896	15	7	210
OCT	6577	352	24	839	17	8	272
NOV	6702	426	34	955	16	7	215
DEC	6462	371	30	790	17	8	224

52/28-8

F-15 C/D APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1979

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN							
FEB							
MAR							
APR							
MAY							
JUN							
JUL	39	3	0	7	13	6	
AUG	255	3	0	21	49	11	
SEP	630	12	0	36	51	14	∞
OCT	513	23	0	58	37	12	∞
NOV	769	19	0	49	35	13	∞
DEC	954	7	0	32	46	16	∞

52/28-9

F-15 C/D APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1980

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	1440	33	0	57	54	23	∞
FEB	1518	33	3	75	54	24	1304
MAR	1933	50	4	135	42	18	699
APR	1742	59	0	141	37	15	742
MAY	1887	93	6	253	28	11	556
JUN	2266	146	3	314	20	8	655
JUL	2454	139	9	284	17	8	367
AUG	1977	124	5	293	16	8	394
SEP	2331	148	1	286	16	8	451
OCT	2742	116	2	214	18	9	881
NOV	2420	178	3	404	17	8	1249
DEC	2737	118	1	238	19	9	1317

F-15 C/D APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1981

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	2523	117	13	251	19	9	452
FEB	2918	143	4	262	22	11	454
MAR	3543	202	7	372	19	10	374
APR	3643	148	13	407	20	10	421
MAY	3500	137	11	340	22	10	345
JUN	4522	136	11	309	28	11	333
JUL	4665	233	16	462	25	11	334
AUG	4220	344	13	613	19	10	335
SEP	3985	159	13	327	17	9	306
OCT	4713	199	28	437	18	9	239
NOV	3866	141	12	305	25	12	237
DEC	3638	91	9	219	28	13	249

52/28-11

F-15 C/D APG-63 D056B RADAR FIELD RELIABILITY DATA
YEAR 1982

WUC 74 FXX

MONTH	HOURS	FAIL	OTH/MAL	TOTAL	3-MONTH MTBM TYPE 1	3-MONTH MTBM TOTAL	3-MONTH MTBM TYPE 2
JAN	3814	255	19	558	23	10	283
FEB	4274	172	18	467	23	9	255
MAR	5674	238	15	582	21	9	265
APR	5491	212	15	461	26	11	322
MAY	5665	294	19	624	23	10	343
JUN	6071	235	21	455	23	11	313
JUL	5329	408	42	819	18	9	208
AUG	5450	234	17	424	19	10	211
SEP	4833	225	9	473	20	9	230
OCT	5376	238	12	546	23	11	412
NOV	4346	248	8	469	20	10	502
DEC	4851	198	17	514	21	10	394

LESSONS LEARNED

F-15 APG-63 PROGRAM LESSONS LEARNED

(1) MILITARY CUSTOMER IS DRIVING FORCE THAT MOTIVATES CONTRACTORS AND SUBCONTRACTORS THROUGH PROGRAM REQUIREMENTS AND COORDINATION BY HIGHLY QUALIFIED PERSONNEL

(2) MANAGEMENT MOTIVATION AND DESIGNER INVOLVEMENT AT BOTH THE PRIME AND SUBCONTRACTOR'S FACILITY NECESSARY FOR SUCCESS

(3) UNATTAINABLE OR UNREASONABLE REQUIREMENTS NEED TO BE ADDRESSED PRIOR TO CONTRACT AWARD AND RESOLVED

(4) FAILURE AND MAINTENANCE RELEVANT GROUND RULES SHOULD BE INCLUDED AS PART OF A WELL-DEFINED DEMONSTRATION PLAN PRIOR TO CONTRACT AWARD

(5) CUSTOMER (NAVY, AIR FORCE, ETC.) R&M MANAGERS MUST HAVE MOTIVATION AND THE ABILITY TO INFLUENCE PROGRAM AND AUTHORITIES TO SOLVE PROBLEMS AS THEY ARISE

46A/1-58

F-15 APG-63 PROGRAM LESSONS LEARNED (CONTINUED)

(6) R&M SHOULD BE EVALUATED UNDER LABORATORY, INITIAL FLIGHT TEST AND FIELD CONDITIONS USING PREVIOUSLY AGREED-TO RULES

(7) R&M GROWTH SHOULD BE REQUIRED AND THOSE DESIGN FEATURES AND IMPROVEMENTS THAT PERMIT ATTAINMENT IDENTIFIED AND INCORPORATED

(8) FINANCIAL INCENTIVES AND PENALTIES TO MOTIVATE SUCCESSFUL COMPLETION OF RELIABILITY TESTING ON SCHEDULE SHOULD BE INCLUDED IN THE CONTRACT

(9) BURN-IN TESTING AT THE PART, LRU, UNIT AND SYSTEM LEVELS AT THE RADAR SUBCONTRACTOR'S FACILITY TO IDENTIFY DESIGN AND MANUFACTURING DEFECTS SHOULD BE PROVIDED FOR. PROVISIONS FOR BURN-IN OF SPARE LRUs AND MODULES SHOULD BE INCLUDED

(10) PRIME CONTRACTOR PERSONNEL SHOULD BE ON-SITE AT LEAST DURING START-UP AND COMPLETION OF RELIABILITY TESTS TO PROVIDE SURVEILLANCE AND QUICK RESOLUTION OF PROBLEMS

F-15 APG-63 PROGRAM LESSONS LEARNED (CONTINUED)

(11) A PARTS CONTROL PROGRAM, AGREED-TO DERATING REQUIREMENTS AND THERMAL ANALYSIS WITH VERIFICATION MEASUREMENTS ARE HIGH PAYOFF ACTIVITIES AND SHOULD BE CONTRACTUALLY REQUIRED

(12) PRODUCTION RELIABILITY DEMONSTRATION TESTING SHOULD BE PHASED OUT WITH MATURE PRODUCTION CONFIGURATION AND BE REPLACED WITH 100% "FAILURE-FREE" BURN-IN/ACCEPTANCE TESTS

(13) RELIABILITY DEMONSTRATION TESTING UNDER LABORATORY CONDITIONS IS MORE USEFUL IN RESOLVING SOFTWARE PROBLEMS THAN HARDWARE PROBLEMS. OTHER MANUFACTURING AND TEST ACTIVITIES PROVIDE CONSIDERABLE DATA ON HARDWARE FAILURES, BUT THE CONTROLLED ENVIRONMENTAL CONDITIONS, CAREFUL REPORTING, AND REPETITIVE MEASUREMENTS OF A FORMAL TEST PROVIDE DATA ON SOFTWARE DISCREPANCIES WHICH MIGHT BE MISSED OR IGNORED UNDER OTHER USE CONDITIONS: SOFTWARE PROBLEMS FREQUENTLY APPEAR ONLY SPORADICALLY

F-15 APG-63 PROGRAM LESSONS LEARNED (CONTINUED)

(14) COINCIDENT WITH EARLY PRODUCTION AIRCRAFT DELIVERIES TO THE TACTICAL TRAINING WING, AN "EAGLE WATCH" TYPE PROGRAM SHOULD BE INITIATED CONSISTING OF DATA COLLECTION, ANALYSIS, PROBLEM RECOGNITION, DEFINITION, AND SOLUTION

(15) RADAR DESIGN, MANUFACTURING PROCESSES, AND PARTS USAGE ARE CONSTANTLY EVOLVING, THUS A HIGH LEVEL OF RELIABILITY AND QUALITY SURVEILLANCE MUST BE MAINTAINED. FOR EVERY PROBLEM SOLVED, A NEW ONE WILL LIKELY ARISE. POST DELIVERY CHANGES HAVE BEEN GREATLY FACILITATED BY SOFTWARE REVISION, BUT SIMPLIFIED, EXPEDITED HARDWARE CHANGES (AS PROVIDED BY CONTRACTOR FIELD TEAMS) ARE REQUIRED

(16) THE DOD MAINTENANCE REPORTING SYSTEMS, 3M AND 66-1, PROVIDE ONLY A GROSS INDICATION OF EQUIPMENT RELIABILITY. MANY OF THE COMPLAINTS ABOUT POOR CORRELATION OF SPECIFIED OR TEST MTBFs TO FIELD RESULTS STEM FROM DIFFERENCES OF MEASUREMENT. ON-SITE CONTRACTOR PERSONNEL CAN PROVIDE VALUABLE ASSISTANCE TO THE DOD MAINTENANCE PERSONNEL AND FEED BACK TO THEIR COMPANY. ON-SITE PERSONNEL COULD REPORT R&M STATUS WHICH MIGHT WELL BE A MORE EFFECTIVE USE OF PROGRAM FUNDS THAN FOR FORMAL DEMONSTRATION TESTS IN LATER PRODUCTION PHASES OF A PROGRAM

(17) CONCURRENCY OF DEVELOPMENT TASKS DEMANDS RAPID CONTRACTOR PROBLEM RESPONSE AND CORRECTIVE ACTION IMPLEMENTATION. THIS WAS SUCCESSFULLY PRACTICED ON THE EARLY "GROWTH" PORTION OF THE F-15 RADAR PROGRAM. HOWEVER, LATER IN THE PROGRAM, RIGID, LENGTHY CHANGE PROCEDURES WERE INITIATED BY THE U.S. AIR FORCE, WHICH STIFLED THE CONTINUATION OF SUCH GROWTH

F-15 APG-63 PROGRAM LESSONS LEARNED (CONTINUED)

(18) ALTHOUGH AN EXTENSIVE BUILT-IN-TEST DESIGN CAN BE INCORPORATED TO DETECT AND ISOLATE FAULTS, IT CANNOT APPROACH THE TROUBLESHOOTING EXPERIENCE OF A WELL-TRAINED RADAR TECHNICIAN.

SINCE THE RADAR IS USUALLY OPERATING OVER AN ENTIRE FLIGHT SORTIE, THE PILOT MAY EXPERIENCE PERFORMANCE ANOMALIES THAT ARE NOT DISCOVERED BY THE BUILT-IN-TEST SYSTEM WHICH IS NOT OPERATING CONTINUOUSLY.

THAT IS, ONLY CERTAIN RADAR FUNCTIONS LEND THEMSELVES TO CONTINUOUS TEST BY MONITORING, I.E., SUCH AS RF DETECTORS. MOST DETAILED BIT INVOLVES THE INTERRUPTION OF NORMAL RADAR OPERATION TO PERFORM SPECIALIZED TESTS WITH SIGNAL INJECTION.

PILOT SQUAWKS INCLUDE AREAS SUCH AS NOISE ON THE DISPLAY (BIRDS), AND TRACKING IRREGULARITIES. BIT SYSTEMS ARE NOT DESIGNED TO BE ABLE TO HANDLE TIME HISTORY EVENTS, BUT ONLY GO/NO-GO TYPES OF FAILURES.

THE PRESENT ANSWER TO THE INTERMITTENT OR PILOT-SQUAWKS-ONLY TYPE OF PROBLEM IS EXTENSIVE TROUBLESHOOTING AIDS IN THE RADAR MAINTENANCE HANDBOOK. THE SOLUTION TO THESE TYPES OF PROBLEMS CAN BE AIDED GREATLY BY THE TYPE OF RADAR TRAINING GIVEN TO MAINTENANCE PERSONNEL. PRESENTLY THIS IS ONLY MINIMAL AND IT IS FELT IT SHOULD BE GREATLY IMPROVED.

F-15 APG-63 PROGRAM LESSONS LEARNED (CONTINUED)

(19) THE VIDEO TAPE RECORDING SYSTEM (VTRS) IS A VALUABLE TROUBLESHOOTING AID FOR RADAR TECHNICIANS AND CAN ALSO BE USED FOR TRAINING. THE VTRS RECORDS THE RADAR DISPLAY ON THE VTRS AND THE HUD DISPLAY AT THE PILOT'S DISCRETION DURING FLIGHT. THE VIDEO TAPE CASSETTE IS AVAILABLE FOR USE IN DEBRIEFING AND CAN BE VIEWED BY TECHNICIANS. THE PILOT CAN SHOW THE TECHNICIAN EXACTLY WHAT HE VIEWED ON THE VTRS FOR RADAR ANOMALIES AND FAULTS SEEN DURING FLIGHT THAT ARE NOT DETECTED OR RECORDED BY BUILT-IN-TEST.